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QUAD4 SEMINAR

Vipperla B. Venkayya
Victoria A. Tischler

Analysis and Optimization Branch
Structures Division

April 1989
(Revised April 1993)

Approved for public release; distribution is unlimited.

FLIGHT DYNAMICS LABORATORY
WRIGHT RESEARCH and DEVELOPMENT CENTER
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433-6523

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This report is prepared for use in conjunction with a four to eight hour course of instruction for training engineers in modeling plates in NASTRAN (NASA STRuctural ANalysis Program). It contains a number of sample problems to illustrate the various capabilities of the QUAD4 element in COSMIC-NASTRAN. In many instances, the results were compared with those obtained from MSC-NASTRAN.

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This technical report has been reviewed and is approved for publication.

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FOREWORD

This technical report is prepared for presentation at training seminars modeling plate elements in NASTRAN (NASA STRuctural ANalysis Program). This training seminar is usually given at NASTRAN User Colloquiums or NASTRAN Applications Short Courses.

INTRODUCTION

NASTRAN (NASA STRuctural ANalysis Program) is the most widely used general purpose structural analysis program in the world. This program was originally developed in the mid-sixties, and the first version was released in 1968., The program developed was sponsored by the National Aeronautics and Space Administration (NASA). This development in the form of enhancements and maintenance was continued until 1972 as a single Government version under the sponsorship of NASA. Since then the Government version is being developed as COSMIC-NASTRAN, while a commercial version is being marketed by McNeal and Swendler Corporation (MSC) as MSC-NASTRAN. Even though the basic structure of these two versions remains the same, there are significant differences in capabilities and efficiencies. Around 1980 the MSC introduced a new plate bending element called the QUAD4 to its element library. It is one of the most versatile plate bending elements, even though its theoretical basis is somewhat controversial. The basic strength of this element is that it was subjected to exclusive numerical testing, and a number of empirical adjustments were made to conform the results to known solutions. The QUAD4 element embodies a number of improvements over the earlier elements (QDMEM, QDMEM1, QDMEM2, QDPLT, QUAD1 and QUAD2).

a. It is an isoparametric formulation.

b. It models inplane (membrane) behavior more realistically.

c. The layered composites modeling capability is extensive.

d. Membrane-bending coupling can be modeled realistically.

e. It is the only plate element with an offset feature.

f. It is a convenient element for modeling laminate plates.

g. The same element can be used in modeling sandwich plates; even though it is not as simple to model sandwich plates with composite face sheets.

h. A single plate element replaced all other elements.

Until around 1987, COSMIC-NASTRAN did not have a similar (QUAD4) capability. The absence of this capability represented a significant inconvenience, in particular, for modeling layered composites. Between 1983-1986 a QUAD4 element was developed under the sponsorship of the Air Force (Flight Dynamics Laboratory) for use in the program ASTROS (Automated Structural Optimization System). At the same time this element was incorporated into COSMIC-NASTRAN. The ASTROS-QUAD4 element is similar to the MSC-QUAD4, but there are significant differences in the theoretical formulation between the two elements.

This report provides an informal background for modeling with the QUAD4 element. It contains over 15 problems to illustrate various options of the element. However, the report was intended only as background material to be used in conjunction with a one-day short course. The section on the theoretical formulation was reproduced verbatim from one of the interim reports of the ASTROS contract.

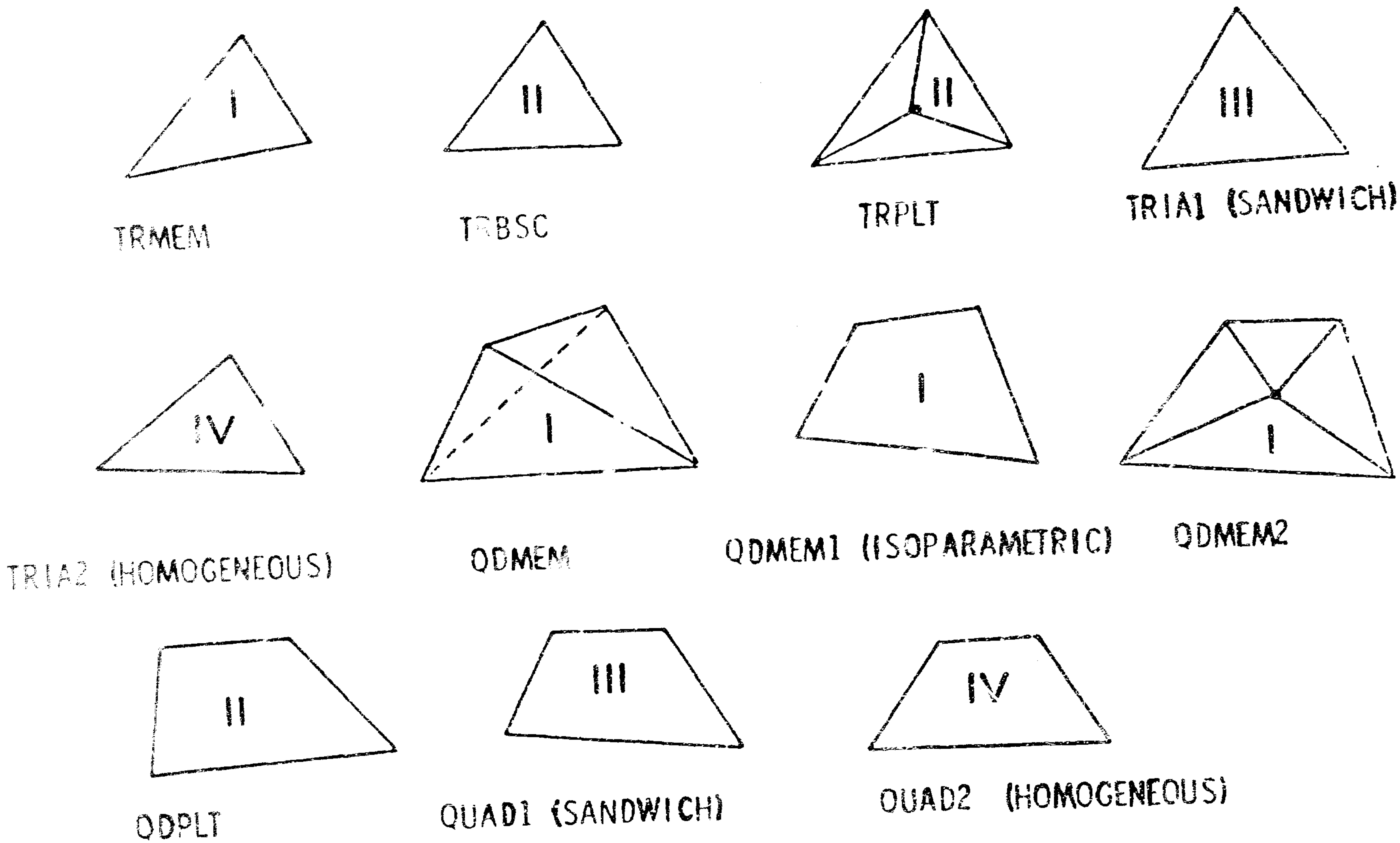
2.0 SEMINAR VIEWGRAPHS

QUAD4 ELEMENT - PURPOSE

- MODEL MEMBRANE BENDING PROBLEMS
- MODEL COMPOSITE PLATES
- MODEL MEMBRANE BENDING COUPLING
- MODEL SANDWICH PLATES IN MEMBRANE BENDING
- REPLACES QDMEM, QDMEM1, QDMEM2, QDPLT, QUAD1, QUAD2, SHEAR

NASTRAN OVERVIEW

STRUCTURAL ELEMENTS IN NASTRAN PLATE ELÉMENTS (II)



SURFACE ELEMENTS

QUAD4 ELEMENT - FEATURES

- ISOPARAMETRIC ELEMENT
- BILINEAR VARIATION OF
  - GEOMETRY
  - DEFORMATION
- PROVIDES STIFFNESS FOR 5 DEGREES OF FREEDOM
- TRANSVERSE SHEAR FLEXIBILITY
- INTERLAMINAR SHEAR STRESSES
- FIVE FAILURE THEORIES

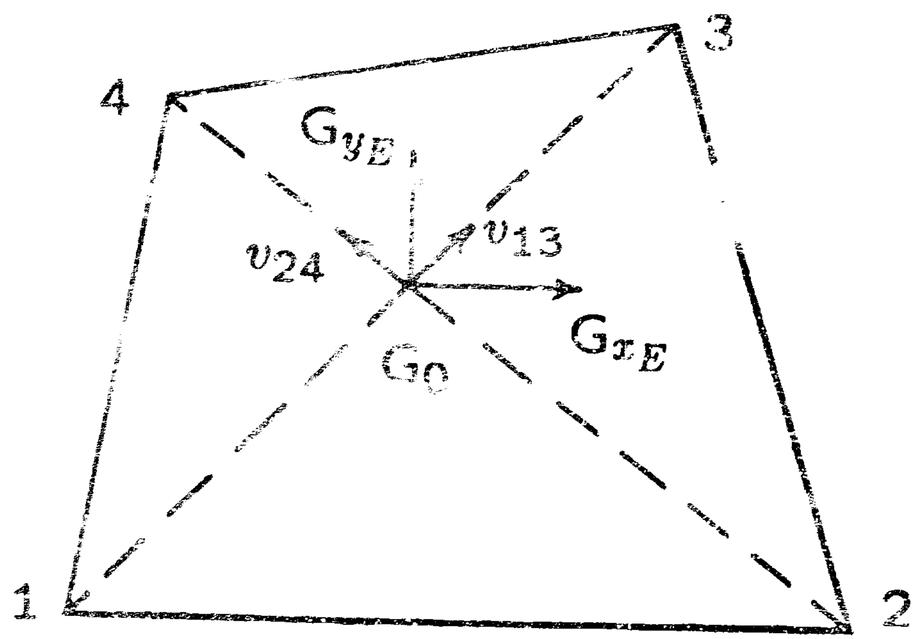
QUAD4 ELEMENT - FEATURES

- ALLOWS MODELING
  - THIN PLATES
  - THICK PLATES
  - HIGH ASPECT RATIO ELEMENTS
  - SKEWED ELEMENTS
  - OFF SET ELEMENTS

- NUMERICAL MODELING OF OUT-OF-PLANE SHEAR STRAINS
- LUMPED MASS MODELS
- CONSISTENT MASS MODELS (PLANNED)
- DIFFERENTIAL STIFFNESS (PLANNED)

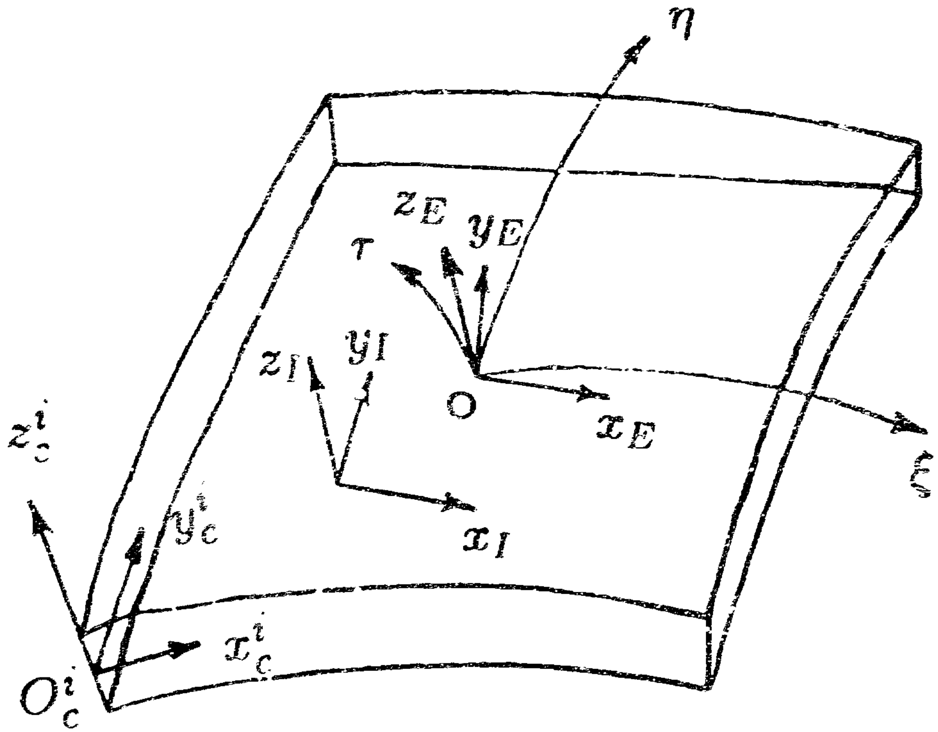
QUAD4 ELEMENT - THEORETICAL OUTLINE

- TWO ELEMENT COORDINATE SYSTEMS
  - DEFINED BY ELEMENT CONNECTIVITY
  - INTERNAL ELEMENT COORDINATE SYSTEM FOR STIFFNESS FORMULATION



Internal Element Coordinate System

QUAD4 ELEMENT - THEORETICAL OUTLINE



Isoparametric Quadrilateral 4-Node Plate & Shell Element

Frame 6

Apr 21, 1988

QUAD4 ELEMENT - SHAPE FUNCTIONS

$$\underset{\sim}{x}_E(\xi, \eta) = N_1 \underset{\sim}{x}^1 + N_2 \underset{\sim}{x}^2 + N_3 \underset{\sim}{x}^3 + N_4 \underset{\sim}{x}^4$$

$$\underset{\sim}{u}_E(\xi, \eta) = N_1 \underset{\sim}{u}^1 + N_2 \underset{\sim}{u}^2 + N_3 \underset{\sim}{u}^3 + N_4 \underset{\sim}{u}^4$$

$N_i \Rightarrow N_i(\xi, \eta) \Rightarrow$ SHAPE FUNCTIONS

$\underset{\sim}{x}^i \Rightarrow$ GRID POINT COORDINATES

$$[x_i,\ y_i,\ z_i]^t$$

$\underset{\sim}{u}^i \Rightarrow$ GRID POINT DISPLACEMENTS

$$[u_i,\ v_i,\ w_i,\ \theta_{xi},\ \theta_{yi},\ \theta_{zi}]^t$$

QUAD4 ELEMENT - SHAPE FUNCTIONS

$$N_i = \frac{1}{4}(1 + \xi\xi_i)(1 + \eta\eta_i)$$

$$\frac{\partial N_i}{\partial \xi} = \frac{1}{4}\xi_i(1 + \eta\eta_i)$$

$$\frac{\partial N_i}{\partial \eta} = \frac{1}{4}\eta_i(1 + \xi\xi_i)$$

QUAD4 - STRAIN DISPLACEMENT RELATIONS

- LINEAR STRAIN - DISPLACEMENT RELATIONS

$$\{\epsilon\} = \begin{pmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \\ \gamma_{yz} \\ \gamma_{zx} \end{pmatrix} = \begin{pmatrix} \frac{\partial u}{\partial x} \\ \frac{\partial v}{\partial y} \\ \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x} \\ \frac{\partial w}{\partial y} + \frac{\partial v}{\partial z} \\ \frac{\partial w}{\partial x} + \frac{\partial u}{\partial z} \end{pmatrix}$$

QUAD4 - STRAIN DISPLACEMENT RELATIONS

- MEMBRANE - BENDING STRAIN - DISPLACEMENT RELATIONS

$$\left\{\begin{array}{c}\epsilon_M \\ \hline \epsilon_B \\ \hline \gamma_{TS}\end{array}\right\}_i = \left(\begin{array}{ccc|ccc} \frac{\partial N_i}{\partial x} & 0 & 0 & & & \\ 0 & \frac{\partial N_i}{\partial y} & 0 & & 0 & \\ \frac{\partial N_i}{\partial y} & \frac{\partial N_i}{\partial x} & 0 & & & \\ \hline & & & \frac{\partial N_i}{\partial x} & 0 & 0 \\ & 0 & & 0 & \frac{\partial N_i}{\partial y} & 0 \\ & & & \frac{\partial N_i}{\partial y} & \frac{\partial N_i}{\partial x} & 0 \\ \hline 0 & 0 & \frac{\partial N_i}{\partial y} & 0 & \frac{\partial N_i}{\partial z} & 0 \\ 0 & 0 & \frac{\partial N_i}{\partial x} & \frac{\partial N_i}{\partial z} & 0 & 0 \end{array}\right) \left\{\begin{array}{c} u_M \\ v_M \\ w_M \\ \hline u_B \\ v_B \\ w_B \end{array}\right\}_i$$

QUAD4 - STRAIN DISPLACEMENT RELATIONS

- RELATION BETWEEN:

$$[u_m \; v_m \; w_m \; u_b \; v_b \; w_b] \quad \text{and} \quad [u \; v \; w \; \theta_x \; \theta_y \; \theta_z]$$

$$\begin{pmatrix} u_M \\ v_M \\ w_M \\ u_B \\ v_B \\ w_B \end{pmatrix}_I = \left(\begin{array}{c|c} T & 0 \\ \hline 0 & \frac{Jt}{2}A \end{array}\right) \begin{pmatrix} u \\ v \\ w \\ \theta_x \\ \theta_y \\ \theta_z \end{pmatrix}_E$$

- JACOBIAN (TRANSFORMATION FROM $\underset{\sim}{x}$ TO $\underset{\sim}{\xi}$)

$$\begin{pmatrix} \frac{\partial N_i}{\partial \xi} \\ \frac{\partial N_i}{\partial \eta} \\ \frac{\partial N_i}{\partial \zeta} \end{pmatrix} = \begin{pmatrix} \frac{\partial x}{\partial \xi} & \frac{\partial y}{\partial \xi} & \frac{\partial z}{\partial \xi} \\ \frac{\partial x}{\partial \eta} & \frac{\partial y}{\partial \eta} & \frac{\partial z}{\partial \eta} \\ \frac{\partial x}{\partial \zeta} & \frac{\partial y}{\partial \zeta} & \frac{\partial z}{\partial \zeta} \end{pmatrix} \begin{pmatrix} \frac{\partial N_i}{\partial x} \\ \frac{\partial N_i}{\partial y} \\ \frac{\partial N_i}{\partial z} \end{pmatrix}$$

QUADA ELEMENT - STRESS - STRAIN RELATIONS

- STRESS AND STRAIN ARE RELATED BY:

$$\begin{Bmatrix} \sigma_M \\ \sigma_B \\ \tau_{TS} \end{Bmatrix} = \begin{pmatrix} G_1 & 0 & 0 \\ 0 & G_2 & 0 \\ 0 & 0 & G_3 \end{pmatrix} \begin{pmatrix} \epsilon_M \\ \epsilon_B \\ \gamma_{TS} \end{pmatrix}_{MEC} - \begin{pmatrix} \epsilon_M \\ \epsilon_B \\ 0 \end{pmatrix}_T$$

or

$$[\sigma]_i = [G]_i \left(\{\epsilon\}_{MEC} - \{\epsilon\}_T \right)_i$$

QUAD4 ELEMENT - STRESS - STRAIN RELATIONS

where

$\{\sigma_M\}$ - Membrane stress vector

$\{\sigma_B\}$ - Bending stress vector

$\{\tau_{TS}\}$ - Transverse shear stress vector

$\{G_1\}$ - Membrane moduli matrix

$\{G_2\}$ - Bending moduli matrix

$\{G_3\}$ - Transverse shear moduli matrix

$\{\epsilon_M\}$ - Membrane strain vector

$\{\epsilon_B\}$ - Bending strain vector

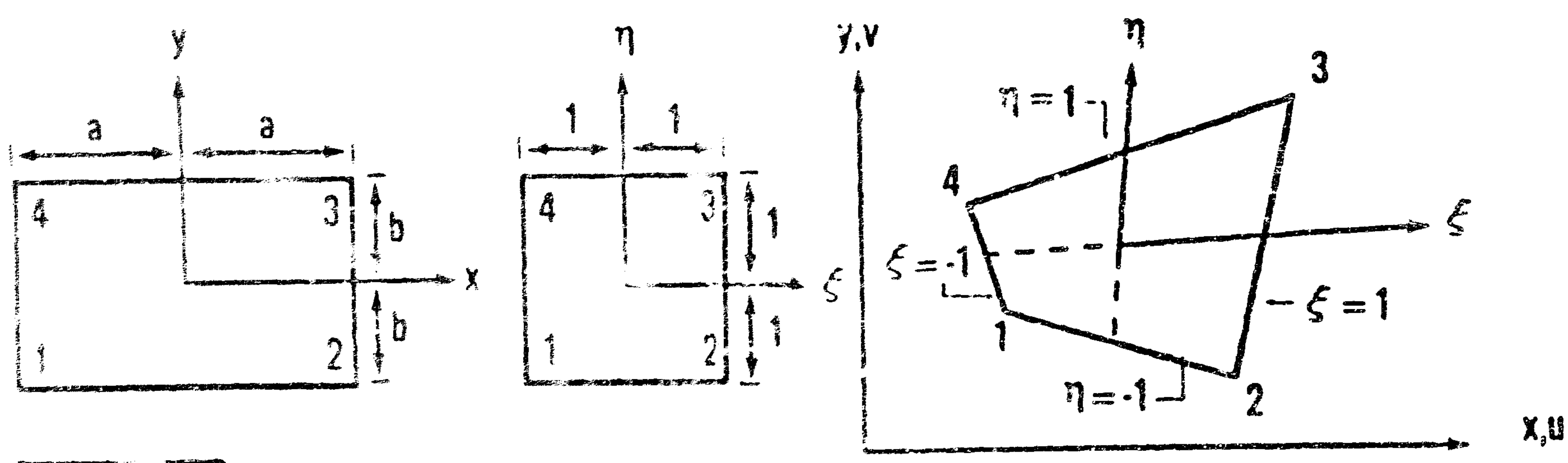
$\{\gamma_{TS}\}$ - Transverse shear strain vector

QUAD4 ELEMENT - STRESS - STRAIN RELATIONS

- MATERIAL CONSTANTS TRANSFORMATION

$$[G]_I = [U]^T [G]_M [U]$$

ISOPARAMETRIC MAPPING



$$\xi = \frac{x}{a}$$

$$\eta = \frac{y}{b}$$

$$x = F_1(\xi, \eta)$$

$$y = F_2(\xi, \eta)$$

$$\underset{\sim}{x} = \underset{\sim}{\phi}_e \, \underset{\sim}{x}_e$$

ISOPARAMETRIC ELEMENTS: SAME POLYNOMIAL APPROXIMATION FOR DISPLACEMENTS AND COORDINATE TRANSFORMATION

Frame 17

FAILURE THEORIES

1) HILL
2) HOFFMAN
3) TSAI-WU
4) MAXIMUM STRESS
5) MAXIMUM STRAIN

FAILURE THEORIES

x_t = Ultimate uniaxial tensile strength in the fiber direction

x_c = Ultimate uniaxial compressive strength in the fiber direction

y_t = Ultimate uniaxial tensile strength perpendicular to the fiber direction

y_c = Ultimate uniaxial compressive strength perpendicular to the fiber direction

s = Ultimate planer shear strength under pure shear loading

E_t = Ultimate uniaxial tensile strain in the fiber direction

E_c = Ultimate uniaxial compressive strain in the fiber direction

F_t = Ultimate uniaxial tensile strain perpendicular to the fiber direction

F_c = Ultimate uniaxial compressive strain perpendicular to the fiber direction

E_s = Ultimate planer shear strain under pure shear loading

FAILURE THEORIES

HILLS's THEORY

$$\frac{\sigma_1^2}{x^2} + \frac{\sigma_2^2}{y^2} - \frac{\sigma_1 \sigma_2}{x^2} + \frac{\tau_{12}^2}{s^2} = FAILURE\ INDEX\ (FI)$$

$x = x_t$ if $\sigma_1 > 0$, x_c if $\sigma_1 < 0$; similarily for y

For the interaction term:

$\frac{\sigma_1 \sigma_2}{s^2}$, $x = x_t$ if $\sigma_1 \sigma_2 > 0$

$x = x_c$ otherwise

FAILURE THEORIES

HOFFMAN's THEORY

$$\left(\frac{1}{x_t} - \frac{1}{x_c}\right)\sigma_1 + \left(\frac{1}{y_t} - \frac{1}{y_c}\right)\sigma_2 + \frac{\sigma_1^2}{x_t x_c} + \frac{\sigma_2^2}{y_t y_c} + \frac{\tau_{12}^2}{s^2} + \frac{\sigma_1 \sigma_2}{x_t x_c} = FI$$

Note that this theory takes into account the difference in the tensile and compressive allowable stresses by using linear terms in the failure equation.

FAILURE THEORIES

TSAI-WU THEORY

$$F_1\sigma_1 + F_2\sigma_2 + F_{11}\sigma_1^2 + F_{22}\sigma_2^2 + 2F_{12}\sigma_1\sigma_2 + F_{66}\tau_{12}^2 = FI$$

$$F_1 = \frac{1}{x_t} - \frac{1}{x_c} \;, \quad F_2 = \frac{1}{y_t} - \frac{1}{y_c} \;,$$

$$F_{11} = \frac{1}{x_t x_c} \;, \quad F_{22} = \frac{1}{y_t y_c} \;, \quad F_{66} = \frac{1}{s^2}$$

F_{12} needs to be determined experimentally from a biaxial test. However, satisfactory results may be obtained by setting it to zero.

Vankarre, Apr 21, 1988

Frame 6

FAILURE THEORIES

MAXIMUM STRESS

$$\sigma_1 \geq x_t \quad , \quad \sigma_1 > 0 \quad ; \quad \sigma_1 \leq -x_c \quad , \quad \sigma_1 < 0$$

$$\sigma_2 \geq y_t \quad , \quad \sigma_2 > 0 \quad ; \quad \sigma_2 \leq -y_c \quad , \quad \sigma_2 < 0$$

$$\tau_{12} \geq s \quad , \quad \tau_{12} > 0 \quad ; \quad \tau_{12} \leq s \quad , \quad \tau_{12} < 0$$

Venkayya Apr 21, 1988

Frame 6

FAILURE THEORIES

MAXIMUM STRAIN

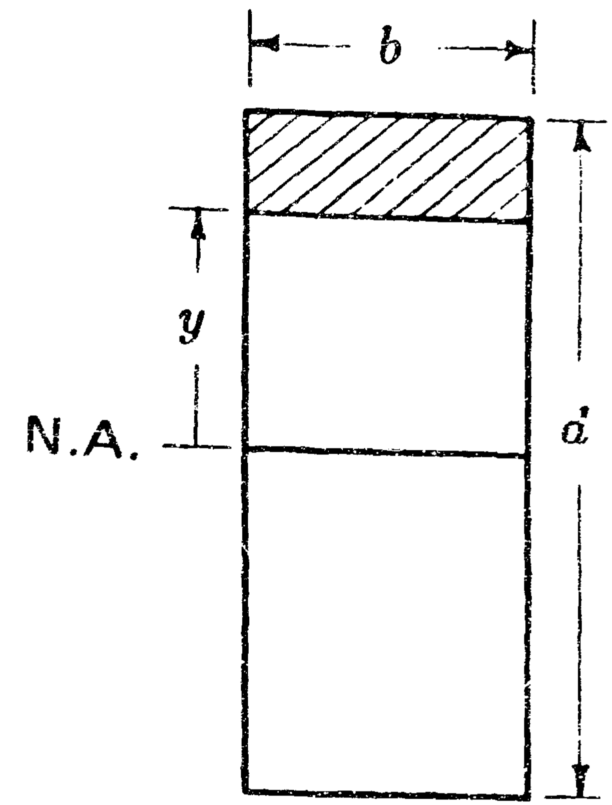
$$\epsilon_1 \geq E_t \quad , \quad \epsilon_1 > 0 \quad ; \quad \epsilon_1 \leq E_c \quad , \quad \epsilon_1 < 0$$

$$\epsilon_2 \geq F_t \quad , \quad \epsilon_2 > 0 \quad ; \quad \epsilon_2 \leq F_c \quad , \quad \epsilon_2 < 0$$

$$\gamma_{12} \geq E_s \quad , \quad \gamma_{12} > 0 \quad ; \quad \gamma_{12} \leq E_s \quad , \quad \gamma_{12} < 0$$

SHEAR REDUCTION FACTORS

1. RECTANGULAR SECTION



$$I = \frac{bd^3}{12} \qquad Q_y = \frac{b}{2}\left(\frac{d^2}{4} - y^2\right)$$

$$\tau_y = \frac{vQ_y}{Ib} = \frac{v}{2I}\left(\frac{d^2}{4} - y^2\right)$$

$v \Rightarrow$ Shear

$$\gamma_y = \frac{v}{2GI}\left(\frac{d^2}{4} - y^2\right)$$

SHEAR REDUCTION FACTORS

Strain energy density at a distance y

$$= \frac{1}{2}\tau_y \gamma_y = \frac{1}{24GI^2}v^2\left(\frac{d^2}{4} - y^2\right)^2$$

TOTAL STRAIN ENERGY $= \frac{v^2}{8GI^2}\int_{-d/2}^{d/2}\left(\frac{d^4}{16} - \frac{d^2y^2}{2} + y^4\right)dy$

Carrying out the integration

TOTAL STRAIN ENERGY $= \frac{1}{2}\frac{v^2}{G(5/6)A} = \frac{1}{2}\frac{v^2}{G(\alpha A)}$

where $\alpha = \frac{5}{6} = 0.833333$

Frame 16

3.0 THEORETICAL DEVELOPMENT OF THE QUAD4 ELEMENT

APPENDIX A

THE QUAD4 ELEMENT

This appendix provides the theoretical development for the QUAD4 element that has been installed into ASTROS. An overview of this element is given in Subsection 5.3.3, while this appendix provides detailed information on the element. This detail is necessary because, unlike the other elements, the ASTROS QUAD4 element has not been documented elsewhere.

A.1 DISPLACEMENT FUNCTIONS

The QUAD4 element has two distinct element coordinate systems. These are the "user defined" element coordinate system as defined by the element connectivity data and the "internal element" coordinate system, which is defined as having its origin at G_o (X^o_E, Y^o_E, Z^o_E). This origin is computed by taking the average of the grid point coordinates. The positive X- and Y-axes of the internal element coordinate system are defined with the aid of two points, G_{xE} and G_{yE} described below.

$\vec{V}_{13}$ and $\vec{V}_{24}$ are defined as the unit diagonal vectors as illustrated in Figure A-1. Thus, the coordinates of points G_{xE} and G_{yE} are given by the following:

$$G_{x_E} = \{(X^o_E + X'_E),\ (Y^o_E + Y'_E),\ (Z^o_E)\}$$

$$G_{y_E} = \{(X^o_E - Y'_E),\ (Y^o_E + X'_E),\ (Z^o_E)\} \qquad \text{(A-1)}$$

where, X^o_E, Y^o_E and Z^o_E are the coordinates of the origins of the internal coordinate system and X'_E and Y'_E are the components of the bisector vector of the unit diagonals V_{13} and V_{24}.

The coordinates of points G_o, G_{xE} and G_{yE}, are used to define the transformation from the internal element coordinate system to the coordinate system in which the grid points are defined. The internal element coordinate system is necessary to correctly handle irregular-shaped and non-planar elements and is henceforth referred to as the "element" (E) coordinate system.

Using 2-D interpolation functions, the geometry field at any point (ξ, η) in the element cross-section (see Figure A-2) is defined, where the nodal curvilinear coordinates are related to the nodal cartesian coordinates system in the element coordinate system by the following relationship:

$$\{X_E(\xi,\eta)\} = \sum_{i=1}^{4} N_i(\xi,\eta)\{X_E^i\}$$

where i refers to grid point i, and

$\{X_E^i\}$ = $\{X_E, Y_E, Z_E\}$ at node i,

$N(\xi,\eta))$ are the interpolation (shape) functions which define the contribution of each node at a given point with the element. These functions and their derivatives are:

$$N_i = 1/4(1 + \xi\xi_i)(1 + \eta\eta_i)$$

$$\frac{\partial N_i}{\partial \eta} = \frac{1}{4}\xi_i(1 + \eta\eta_i) \quad \text{(A-2)}$$

The deformations of the element are also represented with the identical interpolation functions:

$$\{U_E(\xi,\eta)\} = \sum_{i=1}^{4} N_i(\xi,\eta)\{U_E^i\} \quad \text{(A-3)}$$

where $\{U^i{}_E\} = \{U_E, V_E, W_E, \theta x_E, \theta y_E, \theta z_E\}^T$ represents the vector of displacements at grid point i in the element coordinate system.

A.2 STRAIN-DISPLACEMENT RELATIONSHIP

The QUAD4 element incorporates a reduced solid theory for thick shells. According to this theory, the element has five dof at each grid, defined in a coordinate system whose X-Y plane is tangent to the mid-surface of the shell at the given grid point. The z-axis, therefore, is the normal to mid-surface at that point. In our nomenclature, this is called the "C" system (Figure A-2 and A-3).

A generalization of the "C" system, called "I" system, incorporates the characteristics of the "C" system at a general point on the mid-surface of the shell element, normally the integration point (Figure A-2).

In order to establish a common definition for "I" and "C" systems, consider the following steps:

(A) The tangents to mid-surface at a given point (ξ,η) are:

$$\{V_{t_1}\} = \frac{\partial \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_E}{\partial \xi} = \sum_{i=1}^{4} \frac{\partial N_i}{\partial \xi} \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_E^i \tag{A-4}$$

$$\{V_{t_2}\} = \frac{\partial \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_E}{\partial \eta} = \sum_{i=1}^{4} \frac{\partial N_i}{\partial \eta} \begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_E^i \tag{A-5}$$

where

$\begin{Bmatrix} x \\ y \\ z \end{Bmatrix}_E^i$ are the coordinates of grid points in "E" system.

(B) The axes of the new system then follow:

$$\{Z\}_{I/C} = \{V_n\} = \frac{\{V_{t_1}\} \times \{V_{t_2}\}}{|\{V_{t_1}\} \times \{V_{t_2}\}|}$$

$$\{X\}_{I/C} = \frac{\{Y\}_E \times \{Z\}_{I/C}}{|\{Y\}_E \times \{Z\}_{I/C}|} \tag{A-6}$$

$$\{Y\}_{I/C} = \{Z\}_{I/C} \times \{X\}_{I/C}$$

(C) Finally:

$$[TIE] = [\{X\}_I\{Y\}_I\{Z\}_I]^T \tag{A-7}$$

$$[TCE]^i = [\{X\}_c^i\{Y\}_c^i\{Z\}_c^i]^T \tag{A-8}$$

Note that the "C" system is not necessarily invariant when we go from one grid to the next. This is due to the possible warping of the element.

Since the ultimate goal of this discussion is to establish a relationship between the element strains (which are defined in the "I" system), and the nodal displacements (defined in the "E" system), it is necessary to develop a series of transformations along with the strain-displacement relationships.

Consider the five dof's in the "C" system at each grid point "i" to be arranged in the following manner (Figure A-3):

$$\{U\}_c^i = \begin{Bmatrix} u \\ v \\ w \end{Bmatrix}_c^i \quad ; \quad \{\theta\}_c^i = \begin{Bmatrix} \alpha \\ \beta \end{Bmatrix}_c^i \tag{A-9}$$

In order to be compatible with the other dof's in the model, these are related to the six dof at that grid point, defined in the "E" system, by the relationship:

$$\begin{aligned} \{U\}_c^i &= [TCE]^i\{U\}_E^i \\ \{\theta\}_c^i &= \begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}[TCE]^i\{\theta\}_E^i \end{aligned} \tag{A-10}$$

The extra transformation in the rotational case is a result of the difference in the definition of rotations for "C" and "E" systems (Figures A-3 and A-4).

The same five dof's are related to six dof's in the "I" system by using the transformations developed in Equations A-7 and A-8. Considering Equation A-10 and A-3:

$$\begin{aligned} \{U\}_I &= [TIE]\sum_{i=1}^{4} N_i[(TCE)^i]^T\{U\}_c^i = [TIE]\sum_{i=1}^{4} N_i\{U\}_E^i \\ &= \sum_{i=1}^{4} N_i[T]\{U\}_E^i \end{aligned} \tag{A-11}$$

and

$$\begin{aligned} \{\theta\}_I &= [TIE]\sum_{i=1}^{4} N_i[(TCE)^i]^T\{\theta\}_c^i = [TIE]\sum_{i=1}^{4} N_i[(TCE)^i]^T \\ &\begin{bmatrix} 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}[TCE]^i\{\theta\}_E^i = \sum_{i=1}^{4} N_i[A]^i\{\theta\}_E^i \end{aligned} \tag{A-12}$$

Note that while [T] is invariant, [A] depends on the direction of the normal to mid-surface at each grid point.

At a point along the Z-axis of "I" system, at a level of $Z = \zeta t_{I/2}$, where,

$$t_I = \sum_{i=1}^{4} N_i t_i$$

is the thickness of the element evaluated at this particular integration point, the dof's in "I" system may be written in the following form:

$$\{u_M\}_I = \{u\}_I \quad ; \quad \{u_B\}_I = \zeta t_{I/2}\{\theta\}_I \qquad \text{(A-13)}$$

The strain-displacement relationships can now be developed, using these rearranged dof's:

$$\{\epsilon_M\}_I = \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix}_I^M = \begin{Bmatrix} \partial u/\partial x \\ \partial v/\partial y \\ \partial u/\partial y + \partial v/\partial x \end{Bmatrix}_I^M = \begin{bmatrix} \partial/\partial x & 0 & 0 \\ 0 & \partial/\partial y & 0 \\ \partial/\partial y & \partial/\partial x & 0 \end{bmatrix} \{u_M\}_I \qquad \text{(A-14)}$$

$$\{\epsilon_B\}_I = \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix}_I^B = \begin{Bmatrix} \partial u/\partial x \\ \partial v/\partial y \\ \partial u/\partial y + \partial v/\partial x \end{Bmatrix}_I^B = \begin{bmatrix} \partial/\partial x & 0 & 0 \\ 0 & \partial/\partial y & 0 \\ \partial/\partial y & \partial/\partial x & 0 \end{bmatrix} \{u_B\}_I \qquad \text{(A-15)}$$

$$\{\gamma_s\}_I = \begin{Bmatrix} \gamma_{yz} \\ \gamma_{zx} \end{Bmatrix}_I = \begin{Bmatrix} \partial w/\partial y + \partial v/\partial z \\ \partial w/\partial x + \partial u/\partial z \end{Bmatrix} = \left[\begin{array}{ccc|ccc} 0 & 0 & \partial/\partial y & 0 & \partial/\partial z & 0 \\ 0 & 0 & \partial/\partial x & \partial/\partial z & 0 & 0 \end{array}\right] \begin{Bmatrix} u_M \\ u_B \end{Bmatrix}_I \qquad \text{(A-16)}$$

Inserting Equations A-11 through A-13 into Equations A-14 through A-16, and considering the following:

$$\frac{\partial}{\partial z}\{u_B\}_I = \frac{\partial}{\partial z} z\{\theta\}_I = \{\theta\}_I$$

and (A-17)

$$\begin{Bmatrix} \partial/\partial x \\ \partial/\partial y \\ 1 \end{Bmatrix} = \sum_{i=1}^{4} \begin{Bmatrix} \partial N_i/\partial x \\ \partial N_i/\partial y \\ N_i \end{Bmatrix}$$

we arrive at the following general relationships:

$$\{\epsilon_M\}_I = \sum_{i=1}^{4} \begin{bmatrix} \partial N_i/\partial x & 0 & 0 \\ 0 & \partial N_i/\partial y & 0 \\ \partial N_i/\partial y & \partial N_i/\partial x & 0 \end{bmatrix} [T]\{U\}_E^i \qquad \text{(A-18)}$$

$$(\epsilon_B)_I = \frac{\zeta t_I}{2}\sum_{i=1}^{4}\begin{bmatrix}\partial N_i/\partial x & 0 & 0\\ 0 & \partial N_i/\partial y & 0\\ \partial N_i/\partial y & \partial N_i/\partial x & 0\end{bmatrix}[A]^i\{\theta\}_E^i \qquad \text{(A-19)}$$

$$(\gamma_s)_I = \sum_{i=1}^{4}\left[\begin{array}{ccc|ccc}0 & 0 & \partial N_i/\partial y & 0 & N_i & 0\\ 0 & 0 & \partial N_i/\partial x & N_i & 0 & 0\end{array}\right]\left[\begin{array}{c|c}[T] & 0\\ \hline 0 & [A]^i\end{array}\right]\left\{\begin{array}{c}U\\ \hline \theta\end{array}\right\}_E^i \qquad \text{(A-20)}$$

or, collectively:

$$(\epsilon)_I = \left\{\begin{array}{c}\epsilon_M\\ \hline \epsilon_B\\ \hline \gamma_s\end{array}\right\}_I = \sum_{i=1}^{4}\left[\begin{array}{ccc|c}\partial N_i/\partial x & 0 & 0 & \\ 0 & \partial N_i/\partial y & 0 & 0\\ \partial N_i/\partial y & \partial N_i/\partial x & 0 & \\ \hline & 0 & & \frac{\zeta t_I}{2}\begin{bmatrix}\partial N_i/\partial x & 0 & 0\\ 0 & \partial N_i/\partial y & 0\\ \partial N_i/\partial y & \partial N_i/\partial x & 0\end{bmatrix}\\ \hline 0 & 0 & \partial N_i/\partial y & 0 \quad N_i \quad 0\\ 0 & 0 & \partial N_i/\partial x & N_i \quad 0 \quad 0\end{array}\right]\left[\begin{array}{c|c}[T] & 0\\ \hline 0 & [A]^i\end{array}\right]\left\{\begin{array}{c}u\\ v\\ w\\ \theta_x\\ \theta_y\\ \theta_z\end{array}\right\}_E^i \qquad \text{(A-21)}$$

Since the shape functions N_i are defined in terms of the curvilinear coordinates (ξ,η), the shape function derivatives are related to the corresponding Cartesian derivatives in the element [E] coordinate system, by using the rules of partial differentiation, as:

$$\begin{Bmatrix}\partial N_i/\partial \xi\\ \partial N_i/\partial \eta\\ \partial N_i/\partial \zeta\end{Bmatrix} = \begin{bmatrix}\partial x/\partial \xi & \partial y/\partial \xi & \partial z/\partial \xi\\ \partial x/\partial \eta & \partial y/\partial \eta & \partial z/\partial \eta\\ \partial x/\partial \zeta & \partial y/\partial \zeta & \partial z/\partial \zeta\end{bmatrix}\begin{Bmatrix}\partial N_i/\partial x\\ \partial N_i/\partial y\\ \partial N_i/\partial z\end{Bmatrix} \qquad \text{(A-22)}$$

The first and second rows of the transformation matrix (or Jacobian matrix [J]) are the tangent vectors to the surface τ = constant and the third row is the interpolated values of the nodal normals. (Note the nodal normals are evaluated by carrying out the cross product of the two tangent vectors at the node point.)

From Equation A-7 the coordinates in the "I" system are related to the coordinates in the "E" system by the following:

$$\{U\}_I = [TIE]\{U\}_E$$

Therefore, the derivatives are given by:

$$\begin{Bmatrix} \partial N_i/\partial x \\ \partial N_i/\partial y \\ \partial N_i/\partial z \end{Bmatrix} = [\phi] \begin{Bmatrix} \partial N_i/\partial \xi \\ \partial N_i/\partial \eta \\ \partial N_i/\partial \zeta \end{Bmatrix}$$

where (A-23)

$$[\phi] = [TIE]\,[J]^{-1} = \begin{bmatrix} \phi_{11} & \phi_{12} & 0 \\ \phi_{21} & \phi_{22} & 0 \\ \phi_{31} & \phi_{32} & \phi_{33} \end{bmatrix}$$

Note that $\partial N_i/\partial \zeta$ and $\partial N_i/\partial z$ will be zero when the interpolated normal at the integration point coincides with the normal to the mid-surface; e.g., in the case of the flat plate (ϕ_{31} and ϕ_{32} are zero). The zero terms in $[\phi]$, i.e., ϕ_{13} and ϕ_{23}, result from dot products of perpendicular vectors.

A.3 STRESS-STRAIN RELATIONSHIPS

Stresses are related to the previously defined strains by the elasticity matrix [G] (where [G] is partitioned to give separate membrane stresses).

$$\begin{Bmatrix} \sigma_M \\ \hline \sigma_B \\ \hline \tau_{TS} \end{Bmatrix} = \left[\begin{array}{c|c|c} G_1 & 0 & 0 \\ \hline 0 & G_2 & 0 \\ \hline 0 & 0 & G_3 \end{array}\right] \left(\begin{Bmatrix} \epsilon_M \\ \hline \epsilon_B \\ \hline \gamma_{TS} \end{Bmatrix}_{MEC} - \begin{Bmatrix} \epsilon_M \\ \hline \epsilon_B \\ \hline 0 \end{Bmatrix}_T \right)$$

or (A-24)

$$\{\sigma\}_I = [G]_I(\{\epsilon\}_{MEC} - \{\epsilon_T\})_I$$

where

$\{\sigma_M\}$	Membrane stress vector
$\{\sigma_B\}$	Bending stress vector
$\{\tau_{TS}\}$	Transverse shear stress vector
$[G_1]$	Membrane moduli matrix
$[G_2]$	Bending moduli matrix
$[G_3]$	Transverse shear moduli matrix

and subscripts "MEC" and "T" refer to mechanical and thermal, respectively.

The membrane-bending coupling moduli matrix [G4] will be incorporated into the [G] matrix following this discussion of the uncoupled matrices.

All anisotropic, orthotropic and isotropic material properties are supported. The elastic modulus matrix $[G]_M$ is defined in the material coordinate system and transformed into the user defined element coordinate system by means of a transformation angle, θ_M, which references the user defined element X-AXIS or the material coordinate system ID (MCSID) specified by the user. θ_M is in the X-Y plane of the element as shown in Figure A-5.

The elastic modulus matrix in the element coordinate system is:

$$[G]_I = [U]^T[G]_M[U] \tag{A-25}$$

(Note that since the projection of X_I onto the X_E-Y_E plane is parallel to X_E, no extra transformations are required between the "E" and "I" systems.)

The transformation matrix for $[G_1]$, $[G_2]$ and $[G_4]$ is:

$$[U_1] = \begin{bmatrix} \cos^2\theta_M & \sin^2\theta_M & \cos\theta_M\sin\theta_M \\ \sin^2\theta_M & \cos^2\theta_M & -\cos\theta_M\sin\theta_M \\ -2\sin\theta_M\cos\theta_M & 2\sin\theta_M\cos\theta_M & \cos^2\theta_M-\sin^2\theta_M \end{bmatrix} \tag{A-26}$$

and the transformation matrix for $[G_3]$ is:

$$[U_2] = \begin{bmatrix} \cos\theta_M & \sin\theta_M \\ -\sin\theta_M & \cos\theta_M \end{bmatrix} \tag{A-27}$$

For isotropic materials:

(A) Membrane

$$[G_1] = \frac{E}{1-\nu^2}\begin{bmatrix} 1 & \nu & 0 \\ & \nu & 0 \\ \text{SYM} & & \frac{1-\nu}{2} \end{bmatrix} \tag{A-28}$$

(B) Bending

$$[G_2] = \frac{t^3}{12I}[G_1] \tag{A-29}$$

(C) Transverse Shear

$$[G_3] = \frac{t_s}{t} \begin{bmatrix} \beta_1 \frac{(1-\nu)}{2K} & 0 \\ 0 & \beta_2 \frac{(1-\nu)}{2K} \end{bmatrix} \quad \text{(A-30)}$$

where E is the Young's modulus; t is the element thickness at the corresponding integration point, ν is the Poisson's ratio and t_s/t is the transverse shear factor.

Note that in matrix $[G_3]$, the factor "K" is introduced to compensate for the difference in shear distribution though the thickness, which is parabolic and not constant as indicated by the displacement function. The value of K=1.2 is the ratio of the relevant strain energies. The β_i factors, which are derived numerically, are introduced to compensate for the "locking" of the element due to excessive shear stiffness.

For anisotropic materials:

(A) Membrane

$$[G_1] = \begin{bmatrix} G_{11} & G_{12} & G_{13} \\ & G_{22} & G_{23} \\ \text{SYM} & & G_{33} \end{bmatrix} \quad \text{(A-31)}$$

(B) Bending

$$[G_2] = \frac{t^3}{12I} [G_1] \quad \text{(A-32)}$$

(C) Transverse Shear

$$[G_3] = \frac{t_s}{t} \begin{bmatrix} G_{11} & G_{12} \\ G_{12} & G_{22} \end{bmatrix} \quad \text{(A-33)}$$

For orthotropic materials:

(A) Membrane

$$[G_1] = \frac{1}{1-\nu_{12}\nu_{21}} \begin{bmatrix} E_1 & \nu_{12}E_2 & 0 \\ & E_2 & 0 \\ \text{SYM} & & G_{12}(1-\nu_{12}\nu_{21}) \end{bmatrix} \quad \text{(A-34)}$$

(B) Bending

$$[G_2] = \frac{t^3}{12I} [G_1] \tag{A-35}$$

(C) Transverse shear

$$[G_3] = \frac{t_s}{t} \begin{bmatrix} G_{1z} & 0 \\ 0 & G_{2z} \end{bmatrix} \tag{A-36}$$

where E_1 and E_2 are the Young's moduli in the principal material axes, ν_{12} is the major Poisson's ration; G_{12} is the in-plane shear modulus, G_{1z} and G_{2z} are the out-of-plane shear moduli and t_s/t is the transverse shear factor.

The derivation of the $[G_4]$ membrane-bending coupling matrix begins by denoting the strains at the mid-surface as:

$$\{\overset{o}{\epsilon}_M\} = \begin{Bmatrix} \epsilon_x^o \\ \epsilon_y^o \\ \gamma_{xy}^o \end{Bmatrix} \tag{A-37}$$

and the out of plane curvatures as:

$$\{K\} = \begin{Bmatrix} K_x \\ K_y \\ K_{xy} \end{Bmatrix} \tag{A-38}$$

Therefore, the strains at a distance z above the mid-surface of the element are:

$$\{\epsilon\} = \{\overset{o}{\epsilon}_M\} - z\{K\} \tag{A-39}$$

The corresponding 2-D stresses are:

$$\{\sigma\} = [G]_I(\{\overset{o}{\epsilon}_M\} - z\{K\}) \tag{A-40}$$

where $[G]_I$ is a (3x3) matrix of elastic moduli.

The forces and moments per unit length are therefore given by:

$$\{F\} = \int_{z_a}^{z_b} \{\sigma\}\, dz = \int_{z_a}^{z_b} [G]_I(\{\epsilon^o\} - z\{K\})dz \tag{A-41}$$

$$\{F\} = t[G_1]\{\epsilon^o\} + t^2[G_4]\{K\}$$

$$\{M\} = \int_{z_a}^{z_b} \{\sigma\}\, z\,dz = \int_{z_a}^{z_b} [G]_I(-z\{\varepsilon^o\} + z^2\{K\})dz \qquad \text{(A-42)}$$

$$\{M\} = t^2[G_4]\{\varepsilon^o\} + I[G_2]\{K\}$$

where t is the plate thickness and I is the bending inertia. Assuming a linear variation of elastic properties between top and bottom surface.

$$[G_1] = \frac{1}{t}\int_{-t/2}^{t/2} G\,dz = \frac{G_t + G_B}{2} \qquad \text{(A-43)}$$

$$[G_2] = \frac{1}{I}\int_{-t/2}^{t/2} G\,dz = \left(\frac{t^3}{12I}\right)[G_1] \qquad \text{(A-44)}$$

$$[G_4] = \frac{1}{t^3}\int_{-t/2}^{t/2} (-z)G\,dz = -\left[\frac{G_t - G_B}{12}\right] \qquad \text{(A-45)}$$

Note that the membrane-bending stiffness coupling terms vanish for a element whose elastic properties are symmetric relative to the mean plane of the element.

By assuming that the elastic modulus has a linear variation between the top and bottom surfaces, define:

$$G = G_1 + \zeta/2(G_T - G_B) \qquad \text{(A-46)}$$

Therefore, from Equations A-31 and A-32:

(A) Membrane

$$G = G_1 + \zeta/2(-12G_4) \qquad \text{(A-47)}$$

$$G = G_1 - 6\zeta G_4 \qquad \text{(A-48)}$$

(B) Bending

$$G_2 = \frac{G_1 t^3}{12I}$$

$$G = \frac{12I}{t^3} G_2 - 6\zeta G_4 \qquad \text{(A-49)}$$

Matrix $[G_3]$ is not affected since transverse shears are assumed to have no coupling action.

Therefore, the stress-strain relationship, allowing for membrane, bending, transverse shear and membrane-bending coupling is:

$$\begin{Bmatrix} \sigma_M \\ \hline \sigma_{TOT} \\ \hline \tau_{TS} \end{Bmatrix} = \left[\begin{array}{c|c|c} G_1 & G_1 - 6\zeta G_4 & 0 \\ \hline G_1 - 6\zeta G_4 & G_2 & 0 \\ \hline 0 & 0 & G_3 \end{array}\right] \begin{Bmatrix} \epsilon_M \\ \hline \epsilon_B \\ \hline \gamma_{TS} \end{Bmatrix} \tag{A-50}$$

where

$$\{\sigma_M\} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}, \quad \text{Membrane stresses}$$

$$\{\sigma_{TOT}\} = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}_{TOT}, \quad \text{Total membrane and bending stresses}$$

$$\{\sigma_{TS}\} = \begin{Bmatrix} \tau_{yz} \\ \tau_{xz} \end{Bmatrix}, \quad \text{Transverse shear stresses}$$

$$\{\epsilon_M\} = \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix}, \quad \text{Membrane strain}$$

$$\{\epsilon_B\} = \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix}_B, \quad \text{Bending strains}$$

$$\{\gamma_{TS}\} = \begin{Bmatrix} \gamma_{yz} \\ \gamma_{xz} \end{Bmatrix}, \quad \text{Transverse shear strains}$$

A.4 STIFFNESS MATRIX

The element stiffness matrix is derived by minimizing the total potential energy and is given in numerical form by employing the Gauss-quadrature integration method:

$$[K]_E = \Sigma\,\Sigma\,\Sigma\,[B]^T[G][B]W_\xi W_\eta W_\zeta \det\,[J] \tag{A-51}$$

where (ξ, η, ζ) are the Gaussian integration point coordinates and W_ξ, W_η, and W_ζ are the associated weight factors. Det [J] represents the physical volume of the element as calculated at this point, B is the strain displacement relationship of Equation A-21 and G is the stress strain relationship of Equation A-50.

Each element stiffness matrix partition in the element coordinate system, $[K_{ij}]_{EE}$, is transformed to the global coordinate system by the following transformation:

$$[K_{ij}]_G = [TEG]_i^T [K_{ij}]_{EE} [TEG]_i \qquad \text{(A-52)}$$

where $[TEG]_i$ is determined by relating the element coordinate system to the global coordinate system for grid i through the basic coordinate system:

$$[TEG]_i = [TEB]_i [TBG]_i \qquad \text{(A-53)}$$

A.5 CONSISTENT AND LUMPED MASS MATRICES

The consistent mass matrix terms are evaluated, neglecting the rotational inertias associated with the α and β degrees of freedom, by the following expression:

$$M_{ij} = \sum_{n=1}^{4} N_i N_j \, \rho |J| t_n \qquad \text{(A-54)}$$

where N_i is the shape function for node i, ρ is the mass per unit volume, $|J|$ is the physical area of the element and t_n is the element thickness at the integration point.

The lumped mass matrix, which is calculated at the pseudo center (i.e., the average of the element grid coordinates), is prorated to the edges based on the distance of the pseudo center from each edge.

The terms of the lumped mass matrix are evaluated using:

$$M_{ij} = \sum_{i=1}^{4} N_i \, \rho |J| t_n \qquad \text{(A-55)}$$

The transformation of the mass matrix to the global coordinate system is carried out using the same transformation matrices as used for the stiffness matrix in Equation A-52.

A.6 STRESS RECOVERY

The element stresses in partitioned form from Equation A-50 are

$$\begin{Bmatrix} \sigma_M \\ \sigma_{TOT} \\ \tau_{TS} \end{Bmatrix} = \begin{bmatrix} G_1 & G_1 - 6\zeta G_4 & 0 \\ G_1 - 6\zeta G_4 & G_2 & 0 \\ 0 & 0 & G_3 \end{bmatrix} \left\{ \begin{Bmatrix} \epsilon_M \\ \epsilon_B \\ \gamma_{TS} \end{Bmatrix}_{MEC} - \begin{Bmatrix} \epsilon_M \\ \epsilon_B \\ \gamma_{TS} \end{Bmatrix} \right\}$$

or

$$\begin{Bmatrix} \sigma_M \\ \sigma_{TOT} \\ \tau_{TS} \end{Bmatrix} = \begin{bmatrix} G_1 & G_4' & 0 \\ G_4' & G_2 & 0 \\ 0 & 0 & G_3 \end{bmatrix} \left\{ \begin{Bmatrix} \epsilon_M \\ \epsilon_B \\ \gamma_{TS} \end{Bmatrix}_{MEC} - \begin{Bmatrix} \epsilon_M \\ \epsilon_B \\ \gamma_{TS} \end{Bmatrix}_T \right\} \tag{A-56}$$

For a specified grid point temperature, the thermal strain vector is:

$$\{\epsilon_M\}_T = \begin{Bmatrix} \epsilon_x \\ \epsilon_y \\ \gamma_{xy} \end{Bmatrix}_T = \{\alpha_I\}(T_i - T_o) \tag{A-57}$$

where $\{\alpha_I\} = [U]^{-1}\{\alpha_M\}$ is a vector of thermal expansion coefficients in the element coordinate system. [U] is the strain transformation matrix given in Equation A-26 and $\{\alpha_M\}$ is the vector of thermal expansion coefficients in the material axes. T_i and T_o are the specified grid point temperature and mid-surface (stress-free) temperature, respectively.

For a thermal gradient T', the thermal strain vector $\{\epsilon_B\}_T$ is:

$$\{\epsilon_B\}_T = \{\alpha_I\}\left(\frac{\zeta t}{2} T'\right) \tag{A-58}$$

For thermal moments $\{M\}_T$, the thermal strain vector $\{\epsilon_B\}_T$ is:

$$\{\epsilon_B\}_T = \frac{-\zeta t}{2I} [G_2'] \{M\}_T \tag{A-59}$$

NOTE: ASTROS does not support thermal gradient or moments so that the above equations are provided for completeness only.

The in-plane stress vector $\{\sigma\}_z$ at fiber distance z from the mid-surface is:

$$\{\sigma\}_z = \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}_z = \left(\frac{1}{2} - \frac{z}{t}\right) \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}_1 + \left(\frac{1}{2} + \frac{z}{t}\right) \begin{Bmatrix} \sigma_x \\ \sigma_y \\ \tau_{xy} \end{Bmatrix}_1 \tag{A-60}$$

where the stress vectors $\{\sigma_x, \sigma_y, \tau_{xy}\}_1^T$ and $\{\sigma_x, \sigma_y, \tau_{xy}\}_2^T$ are the bottom and top fiber stress vectors, respectively.

If a temperature T_i is specified at the point where outer fiber stresses are to be calculated, the additional thermal stress due to the difference between the specified temperature and a temperature that would be produced by a uniform thermal gradient T' or thermal moments $\{M\}_T$ is calculated using:

$$\{\Delta\sigma\}_T = [G_2]\{\alpha_I\}(T_i - T_o - T'z) \quad \text{(A-61)}$$

for a thermal gradient T', and

$$\{\Delta\sigma\}_T = -z\frac{\{M\}_T}{I} - [G_2]\{\alpha\}T_i \quad \text{(A-62)}$$

A.7 FORCE RESULTANTS

The forces at the mid-surface are evaluated by taking the average stress values over the element thickness:

(A) Forces

$$\{F\} = \begin{Bmatrix} F_x \\ F_y \\ F_{xy} \end{Bmatrix} = (\{\sigma\}_{z1} + \{\sigma\}_{z2})\,\frac{t}{2} \quad \text{(A-63)}$$

(B) Moments

$$\{M\} = \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix} = (\{\sigma\}_{z1} - \{\sigma\}_{z2})\,\frac{I}{2} \quad \text{(A-64)}$$

(C) Transverse Shear Forces

$$\{Q\} = \begin{Bmatrix} Q_x \\ Q_y \end{Bmatrix} = (\{\tau\}_{z1} + \{\tau\}_{z2})\,\frac{t}{2} \quad \text{(A-65)}$$

where stress vectors $\{\sigma\}_{z1}$, $\{\sigma\}_{z2}$ are stresses at the integration points (default option) or at grid points (if requested) and, similarly, $\{\tau\}_{z1}$ and $\{\tau\}_{z2}$ are the transverse shear stresses.

A.8 THERMAL LOAD VECTOR

The thermal load vector is computed as:

$$\{P_T\} = \int_V [B][G]\{\epsilon\}_T \, dv \quad \text{(A-66)}$$

where the load vector $\{P_T\}$ is defined as:

$$\{P_T\} = \begin{Bmatrix} F_T \\ ---- \\ M_T \end{Bmatrix} \tag{A-67}$$

where $\{F_T\}$ and $\{M_T\}$ are the thermal forces and moments, respectively.

The thermal strain vector is:

$$\{\epsilon_T\} = \begin{Bmatrix} \epsilon M_T \\ ----- \\ \epsilon B_T \end{Bmatrix} = \begin{Bmatrix} \alpha_M \\ ---- \\ \alpha_B \end{Bmatrix} \Delta T \tag{A-68}$$

where $\{\epsilon M\}_T$ and $\{\epsilon B\}_T$ are the thermal membrane and bending strains, and correspondingly $\{\alpha_M\}$ and $\{\alpha_B\}$ are the thermal coefficients of expansion for membrane and bending. ΔT is dependent on the temperature loading being specified.

(A) For a specified grid point temperature the thermal membrane strain vector, $\{\epsilon M\}_T$, is:

$$\{\epsilon_M\} = \{\alpha_M\}(T_i - T_o) \tag{A-69}$$

T_i = Grid point temperature

T_o = Reference (stress-free) temperature

(B) For a thermal gradient, the thermal bending strain vector, $\{\epsilon B\}_T$, is:

$$\{\epsilon_B\} = \{\alpha_B\} \left(-\frac{\zeta t}{2} T'\right) \tag{A-70}$$

(C) For thermal moments, the thermal bending strain vector, $\{\epsilon B\}_T$, is:

$$\{\epsilon_B\} = [G_2]\{M\}_T \frac{\zeta t}{2I} \tag{A-71}$$

NOTE: ASTROS does not support thermal gradients or moments so that the above equations are provided for completeness only.

A.9 LAMINATED COMPOSITE MATERIALS

The capability to model a stack of layers with a single QUAD4 element is detailed including the computation of equivalent "single layer" properties, i.e., membrane, bending transverse shear and membrane-bending coupling. The recovery of element forces, layer and interlaminar shear stresses and the computation of ply failure indices is also described in the following overview of theory.

A.9.1 Overview of Theory

The calculation of the "overall" properties for the laminated composite elements is based on the classical lamination theory with the following assumptions:

(A) Each of the lamina is in a state of plane stress.

(B) The laminate is presumed to consist of perfectly bonded lamina.

(C) The bonds are presumed to be infinitesimally thin and non-shear deformable. That is, the displacements are continuous across the lamina boundaries so that lamina can not slip relative to one another. Thus, the laminate behaves as a single layer with "special" properties.

The material properties of laminated composite materials are reflected in the following force-strain relationship:

$$\begin{Bmatrix} F \\ \hline M \\ \hline V \end{Bmatrix} = \left[\begin{array}{c|c|c} t\ G_1 & t^2 G_4 & 0 \\ \hline t^2 G_4 & I\ G_2 & 0 \\ \hline 0 & 0 & t_s\ G_3 \end{array}\right] \begin{Bmatrix} \epsilon_M - \epsilon_M^T \\ \hline K - K^T \\ \hline \gamma \end{Bmatrix} \qquad \text{(A-72)}$$

where

$$\{F\} = \begin{Bmatrix} F_x \\ F_y \\ F_{xy} \end{Bmatrix}, \quad \text{Membrane forces per unit length.}$$

$$\{M\} = \begin{Bmatrix} M_x \\ M_y \\ M_{xy} \end{Bmatrix}, \quad \text{Bending moments per unit length.}$$

$$\{V\} = \begin{Bmatrix} V_x \\ V_y \end{Bmatrix}, \quad \text{Transverse shear forces per unit length.}$$

and the remaining terms have been defined previously.

The G_1, G_2, and G_4 terms are defined by the following:

$$G_1 = \frac{1}{t} \int [G_E]\ dz$$

$$G_2 = \frac{1}{I} \int z^2\ [G_E]\ dz \qquad \text{(A-73)}$$

$$G_4 = \frac{1}{t} \int -z\ [G_E]\ dz$$

The limit on the integration are from the bottom surface to the top surface of the laminated composite. The elasticity matrix $[G_E]$ has the following form for isotropic materials:

$$[G_E] = \begin{bmatrix} \frac{E}{1-\nu^2} & \frac{\nu E}{1-\nu^2} & 0 \\ \text{SYM} & \frac{E}{1-\nu^2} & 0 \\ & & G \end{bmatrix} \qquad \text{(A-74)}$$

$$G = \frac{E}{2(1+\nu)} \qquad \text{(A-75)}$$

For orthotropic materials, matrix $[G_E]$ is:

$$[G_E] = \begin{bmatrix} \frac{E_1}{1-\nu_1\nu_2} & \frac{\nu_1 E_2}{1-\nu_1\nu_2} & 0 \\ \text{SYM} & \frac{E_2}{1-\nu_1\nu_2} & 0 \\ & & G_{12} \end{bmatrix} \qquad \text{(A-76)}$$

Equation A-73 may be rewritten as:

$$[G_{ij}]_1 = \frac{1}{t} \sum_{K=1}^{N} [\bar{G}_{ij}]^K (Z_K - Z_{K-1})$$

$$[G_{ij}]_2 = \frac{1}{3t} \sum_{K=1}^{N} [\bar{G}_{ij}]^K (Z_K^3 - Z_{K-1}^3) \qquad \text{(A-77)}$$

$$[G_{ij}] = \frac{-1}{2t^2} \sum_{K=1}^{N} [\bar{G}_{ij}]^K (Z_K^2 - Z_{K-1}^2)$$

where $[\bar{G}_{ij}]^K$ is the reduced moduli matrix evaluated for each lamina K after transforming the lamina property matrix from the fiber to the element material axes.

Z_K and Z_{K-1} are the top and bottom distances of lamina K from the geometric middle plane of the laminate, as illustrated in Figure A-6, and N is the number of laminae (or plies). Note that the plies are numbered serially starting with 1 at the bottom layer. The bottom layer is defined as the surface with the largest -z value in the element coordinate system. If the option to model membrane-only elements is exercised, matrices $[G_2]$, $[G_3]$, and $[G_4]$ are set to zero.

If the user defined element axis is not coincident with the element material axis, the user specified transformation angle θ_M, which references the element X-axis, is added to the layer orientation angle. The property matrices $[G_1]$, $[G_2]$, and $[G_4]$ are then transformed to the user defined element axis using the following equation:

$$[G_E] = [U]^T [G_M] [U] \tag{A-78}$$

where

$$[U] = \begin{bmatrix} \cos^2\theta & \sin^2\theta & \cos\theta\sin\theta \\ \sin^2\theta & \cos^2\theta & -\cos\theta\sin\theta \\ -2\sin\theta\cos\theta & 2\sin\theta\cos\theta & \cos^2\theta - \sin^2\theta \end{bmatrix} \tag{A-79}$$

The transverse shear flexibility $(G_3]$ matrix is defined by:

$$[G_3] = \begin{bmatrix} G_{11} & G_{12} \\ G_{12} & G_{22} \end{bmatrix} \tag{A-80}$$

and the corresponding matrix transformed into the user-defin[illegible] element coordinate [illegible]stem is given by:

$$[G] = [W]^T [G_M] [W] \tag{A-81}$$

where

$$[W] = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \tag{A-82}$$

The derivation of the transverse shear flexibility matrix $[G_3]$ for the laminate is considered [illegible]xt.

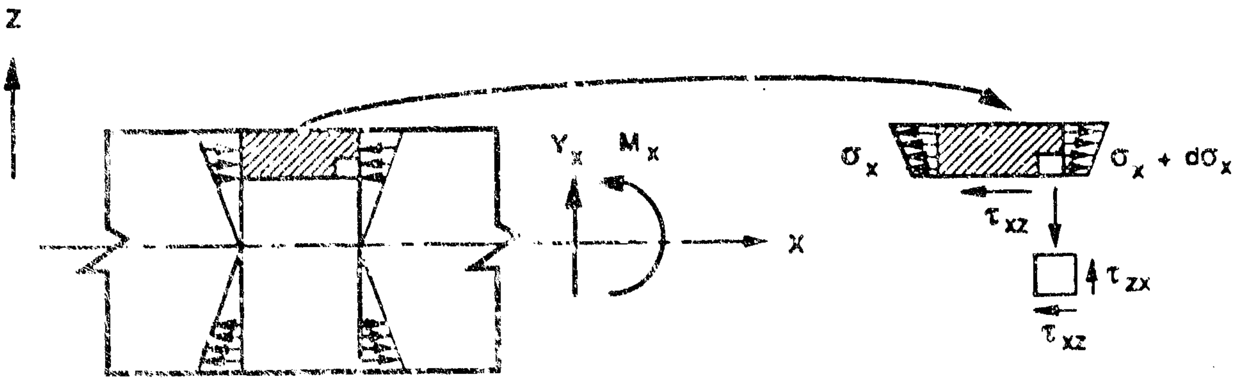
The mean value of the transverse shear modulus, G, for the laminated composite is defined in terms of the transverse shear strain energy, U, through the depth as:

$$U = \frac{V^2}{2Gt} = \frac{1}{2} \int \frac{[\tau(z)]^2}{G(z)} dz \tag{A-83}$$

A unique mean value of transverse shear strain is assumed to exist for both the x- and y-components of the element coordinate system, but for ease of discussion, only the evaluation of an uncoupled x-component of the shear moduli will be illustrated here. From Equation A-83, the mean value of transverse shear modulus is written in the following form:

$$\frac{1}{G_x} = \frac{\bar{x}}{V_x^2} \sum_{i=1}^{N} \int_{Z_{i-1}}^{Z_i} \frac{(\tau_{zx}(z))^2}{(G_x)_i} dz \qquad \text{(A-84)}$$

where G is an "average" transverse shear coefficient used by the element code and $(G_x)_i$ is the local shear coefficient for layer i. To evaluate Equation A-84, it is necessary to obtain an expression for $[\tau_{zx}(z)]$. This is accomplished by assuming that the x- and y-components of stress are decoupled from one another. This assumption allows the desired equation to be deduced through an examination of a beam of unit cross-sectional width.



The equilibrium conditions in the horizontal direction and for total moment are:

$$\frac{\partial \tau_{xz}}{\partial z} + \frac{\partial \sigma_x}{\partial x} = 0 \qquad \text{(A-85)}$$

$$V_x + \frac{\partial M_x}{\partial x} = 0 \qquad \text{(A-86)}$$

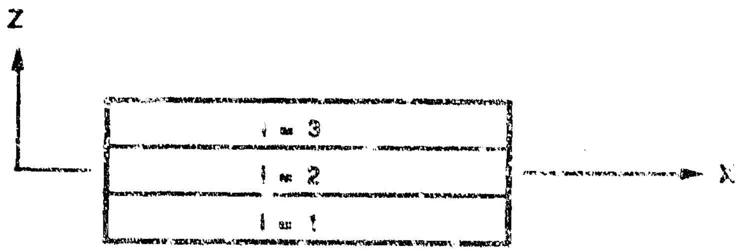
If the location of the neutral surface is denoted by $\bar{z}_x$ and ρ is the radius of curvature of the beam, the axial stress, σ_x, is expressed in the form:

$$\sigma_x = \frac{\bar{E}(\bar{z}_x - z)}{(EI)_x} M_x \qquad \text{(A-87)}$$

Equation A-87 is differentiated with respect to x and combined with Equations A-85 and A-86. For constant E_x, the result is integrated to yield the following expression:

$$\tau_{xz} = C_i + \frac{V_x}{(EI)_x}\left[\bar{z}_x z - \frac{z^2}{2}\right] E_{x_i} \quad z_{i-1}<z<z_i \qquad \text{(A-88)}$$

Equation A-88 is used in the analysis of n-ply laminates because sufficient conditions exist to determine the constants C_i (i=1,2,.....n) and the "directional bending center," $\bar{z}_x$. For example, consider the following laminated configuration:



At the bottom surface (i=1, $z=z_o$, and $\tau_{xz}=0$), therefore:

$$C_1 = \frac{-V_x}{(EI)_x}\left[\bar{z}_x z_o - \frac{z_o^2}{2}\right] E_{x_1} \qquad \text{(A-89)}$$

and for the first ply at the interface between plies i=1 and i=2 ($z=z_1$):

$$(\tau_{xz})_1 = \frac{V_x}{(EI)}\left[\bar{z}_x(z_1-z_0) - \frac{1}{2}(z_1^2-z_0^2)\right] E_{x_1} \qquad \text{(A-90a)}$$

At this interface between plies i=1 and i=2,

$$(\tau_{xz})_2 = C_2 + \frac{V_x}{(EI)_x}\left[\bar{z}_x z_1 - \frac{z_1^2}{2}\right] E_{x_2} \qquad \text{(A-90b)}$$

and since $(\tau_{xz})_2 = (\tau_{xz})_1$ at $z=z_1$:

$$C_2 = (\tau_{xz})_1 - \frac{V_x E_{x_2}}{(EI)_x}\left[\bar{z}_x z_1 - \frac{1}{2} z_1^2\right] \qquad \text{(A-91)}$$

Then, in the ply, $Z_1 < Z < Z_2$, the shear is:

$$\tau_{xz}(z) = (\tau_{xz})_1 + \frac{V_x E_{x2}}{(\bar{EI})_x} [\bar{z}_x(z-z_1) - \frac{1}{2}(z^2-z_1^2)] \quad \text{(A-92)}$$

In general, for any ply $z_{i-1} < z < z_i$, the shear is:

$$\tau_{xz}(z)_i = (\tau_{xz})_{i-1} + \frac{V_x E_{xi}}{(\bar{EI})_x} [\bar{z}_x(z-z_{i-1}) - \frac{1}{2}(z^2-z_{i-1}^2)] \quad \text{(A-93)}$$

At any ply interface, z_i, the shear is therefore:

$$(\tau_{xz})_i = \frac{V_x}{(\bar{EI})_x} \sum_{j=1}^{i} E_{xj} T_j [\bar{z} - \frac{1}{2}(z_j + z_{j-1})] \quad \text{(A-94)}$$

where $T_j = z_j - z_{j-1}$.

Note that the shear at the top face, $(\tau_{xz})_n$, is zero and therefore:

$$(\tau_{xz})_n = \frac{V_x}{(EI)_x} \left[\bar{z}_x \sum_{j=1}^{n} E_{xj} T_j \sum_{j=1}^{n} E_{xj} T_j \frac{(z_j+z_{j-1})}{2}\right] = 0 \quad \text{(A-95)}$$

Equation A-95 proves that if Z_x is the bending center, the shear at the top surface must be zero.

A better form of Equation A-93, for this purpose, is:

$$[\tau_{xz}(z)]_i = \frac{V_x E_{xi}}{(\bar{EI})_x} \left(f_{xi} + \bar{z}(z-z_{i-1}) - \frac{1}{2}(z^2-z_{i-1}^2) \right) \quad \text{(A-96)}$$

where

$$f_{xi} = \frac{1}{E_{xi}} \sum_{j=1}^{i-1} E_{xj} T_j [\bar{z}_x - \frac{1}{2}(z_j+z_{j-1})] \quad \text{(A-97)}$$

Substituting Equation A-96 into Equation A-84 yields:

$$\frac{1}{G_x} = \frac{T}{(\bar{EI})_x^2} \sum_{i=1}^{n} \frac{1}{G_{xi}} R_{xi} \quad \text{(A-98a)}$$

where

$$R_{xi} = (E_{xi})^2 \, T_i \left[(fx_i + (\bar{z}_x - z_{i-1})T_i - \frac{1}{3} T_i^2) fx_i + (\frac{1}{3}(\bar{z}_x - 2z_{i-1}) - \frac{1}{4} T_i)\, \bar{z}_x T_i^3 + (\frac{1}{3} z_{i-1}^3 + \frac{1}{4} z_{i-1} T_i + \frac{1}{20} T_i^3) T_i^3 \right] \quad \text{(A-98b)}$$

This expression for the inverse shear modulus for the x-direction is generalized to provide for the calculation of each term in the two-by-two matrix of shear moduli as:

$$[\bar{G}_{kl}] = \left[\frac{T}{(EI)^2_{kk}} \sum_{i=1}^{n} [G^i_{kl}]^{-1} R_{ki} \right]^{-1} \quad \text{(A-99)}$$

where

$k = 1,2$

$l = 1,2$

Note that if no shear is given, $[G^i]^{-1} = 0$, and also that, in Equation A-99:

$(\overline{EI})_{11}$ = 1,1 term of I x $[G_2^*]$

$(\overline{EI})_{22}$ = 2,2 term of I x $[G_2^*]$

where $[G^*_2]$ is calculated in the same manner as $[G_3]$ except that Poisson's ratio is set to zero. The moduli for individual plies are provided through user input. Because $G_{12} \neq G_{21}$, in general, an average value is used for the coupling terms.

$$[G_3] = \begin{bmatrix} G_{11} & (\bar{G}_{12})_{AVG} \\ (\bar{G}_{12})_{AVG} & G_{22} \end{bmatrix} \quad \text{(A-100)}$$

A.9.2 <u>Element Layer Stress Recovery</u>

The linear strain variation is given by:

$$\{\epsilon_x\} = \{\epsilon_M\} - z\{K\} \quad \text{(A-101)}$$

where

$\{\epsilon_X\}$ = Layer strain vector in the element coordinate system.

$\{\epsilon_M\}$ = Reference surface strain in the element coordinate system.

$\{K\}$ = Reference surface curvatures in the element coordinate system.

Z = Distance of the mid-surface of the layer k from the laminate reference surface.

The individual layer stress vector in the fiber coordinate system is:

$$\{\sigma_L\} = [G_L]\ [T]\ \{\epsilon_X\} \qquad \text{(A-102)}$$

where

$\{\sigma_L\}$ = Layer stress vector in the fiber coordinate system.

$[G_L]$ = Stress-strain matrix in the fiber coordinate system.

$[T]$ = Transformation matrix to transform strains from element coordinate system to fiber coordinate system.

$\{\epsilon_X\}$ = Layer strain vector in the element coordinate system.

For element temperature and/or thermal gradients, the strain vector has to be corrected for thermal effects before applying Equation A-103:

$$\{\epsilon_X\} = \{\epsilon_X'\} - \{\alpha\}\ (T + zT') \qquad \text{(A-103)}$$

and for thermal moments

$$\{\epsilon_X\} = \{\epsilon_X\} - \{\epsilon_X\}^T \qquad \text{(A-104)}$$

where

$\{\epsilon_X'\}$ = Mechanical strains.

$\{\alpha\}$ = Thermal coefficients of expansion in the element coordinate system.

T = Element temperature.

T' = Element thermal gradient.

z = Distance from the middle of the layer to the laminate reference surface.

$\{\epsilon_X\}^T$ = Layer strains due to thermal moments in the element coordinate system.

The thermal strain vector due to applied thermal moments is determined by substituting for {M} in Equation A-73 and solving for the reference surface strains and curvatures, $\{\epsilon^T{}_M\}$ and $\{K^T\}$, respectively.

A.9.3 Interlaminar Shear Stresses

The interlaminar shear stress τ_{yz}, τ_{xz} can be computed at any ply interface from Equation A-96.

A.9.4 Force Resultants

Forces and moments for the element are computed using:

$$\{F\} = \sum_{i=1}^{N} \{\sigma_x\} T_i$$

$$i=1, N \text{ (No. of layers)} \qquad \text{(A-105)}$$

$$\{M\} = \sum_{i=1}^{N} -z_i T_i \{\sigma_x\}$$

where

{F} = In-plane force resultants.

{M} = Out-of-plane moments.

$\{\sigma_x\}$ = Stresses in the element coordinate system.

T_i = Layer thickness.

z_i = Distance from the middle of the layer to the laminate reference surface.

A.9.5 Failure Indices

Failure indices assume a value of one on the periphery of a failure surface in stress space. If the failure index is less than one, the lamina stress is interior to the periphery of the failure surface and the lamina is assumed "safe" and if it is greater than one the lamina is assumed to have "failed." The failure indices represent a phenomenological failure criterion, because only the occurrence of failure is predicted.

The analytical definition of a failure surface in stress space for a lamina subjected to biaxial (planar) states of stress is provided via the following failure theories.

(1) HILL

(2) HOFFMAN

(3) TSAI-WU

(4) MAXIMUM STRESS

(5) MAXIMUM STRAIN

In the analysis of laminated composites, which are typically orthotropic materials (possibly exhibiting unequal properties in tension and compression), the strength of orthotropic lamina is a function of body orientation relative to the imposed stress. In order to determine the structural integrity of the lamina, a set of intrinsic strength properties (allowable stresses or allowable strains) in the principal material directions are defined as:

X_t — Ultimate uniaxial tensile strength in the fiber direction,

X_c — Ultimate uniaxial compressive strength in the fiber direction,

Y_t — Ultimate uniaxial tensile strength perpendicular to the fiber direction,

Y_c — Ultimate uniaxial compressive strength perpendicular to the fiber direction,

S — Ultimate planar shear strength under pure shear loading,

E_t — Ultimate uniaxial tensile strain in the fiber direction,

E_c — Ultimate uniaxial compressive strain in the fiber direction,

F_t — Ultimate uniaxial tensile strain perpendicular to the fiber direction,

F_c — Ultimate uniaxial compressive strain perpendicular to the fiber direction, and

E_s — Ultimate planar shear strain under pure shear loading.

For most composite materials, the planar shear strengths and strains are equal for positive and negative shear loadings.

The five failure theories and a bonding failure index are now described:

HILL'S THEORY

$$\frac{\sigma_1^2}{X^2} + \frac{\sigma_2^2}{Y^2} - \frac{\sigma_1\sigma_2}{X^2} + \frac{\tau_{12}^2}{S^2} = \text{FAILURE INDEX (FI)} \qquad \text{(A-106)}$$

and $X=X_t$ if σ_1 is positive, and X_c if σ_1 is negative; similarly for y. For the interaction term, $(\sigma_1\sigma_2)/X^2$, $X=X_t$ if $\sigma_1\sigma_2$ is positive $X=X_c$ otherwise.

HOFFMAN'S THEORY

$$\left(\frac{1}{X_t} - \frac{1}{X_c}\right)\sigma_1 + \left(\frac{1}{Y_t} - \frac{1}{Y_c}\right)\sigma_2 + \frac{\sigma_1^2}{X_tX_c} + \frac{\sigma_2^2}{Y_tY_c} + \frac{\tau_{12}^2}{S^2} + \frac{\sigma_1\sigma_2}{X_tX_c} = \text{FI} \qquad \text{(A-107)}$$

Note that this theory takes into account the difference in the tensile and compressive allowable stresses by using linear terms in the failure equation.

TSAI-WU THEORY

This quadratic interaction theory allows for the strength predictions wherein interaction among stress components can be considered in determining strengths in a biaxial field. Thus, in the case of an orthotropic lamina in a general state of planar stress:

$$F_1\sigma_1 + F_2\sigma_2 + F_{11}\sigma_1^2 + F_{22}\sigma_2^2 + 2F_{12}\sigma_1\sigma_2 + F_{66}\tau_{12}^2 = \text{FI} \qquad \text{(A-108)}$$

$$F_1 = \frac{1}{X_t} - \frac{1}{X_c}, \quad F_2 = \frac{1}{Y_t} - \frac{1}{Y_c},$$

$$F_{11} = \frac{1}{X_tX_c}, \quad F_{22} = \frac{1}{Y_tY_c}, \quad F_{66} = \frac{1}{S^2} \qquad \text{(A-109)}$$

and F_{12} needs to be determined experimentally from a biaxial test. However, satisfactory results may be obtained by setting it to zero.

MAXIMUM STRESS

Failure is assumed to occur when any one of the stress components is equal to its corresponding intrinsic strength property. In mathematical form, the Maximum Stress theory is given by:

$$\sigma_1 \geq X_t,\ \sigma_1 > 0 \quad ; \quad \sigma_1 \leq -X_c,\ \sigma_1 < 0$$

$$\sigma_2 \geq Y_t,\ \sigma_2 > 0 \quad ; \quad \sigma_2 \leq -Y_c,\ \sigma_2 < 0 \qquad \text{(A-110)}$$

$$\tau_{12} \geq S,\ \tau_{12} > 0 \quad ; \quad \tau_{12} \leq S,\ \tau_{12} < 0$$

where the intrinsic strength properties are as defined previously.

MAXIMUM STRAIN

The Maximum Strain theory is analogous to the Maximum Stress theory. Failure is assumed to result when any one of the strain components is equal to its corresponding intrinsic ultimate strain. In mathematical form the Maximum Strain theory is given by:

$$\epsilon_1 \geq E_t,\ \epsilon_1 > 0 \quad ; \quad \epsilon_1 \leq E_c,\ \epsilon_1 < 0$$

$$\epsilon_2 \geq F_t,\ \epsilon_2 > 0 \quad ; \quad \epsilon_2 \leq F_c,\ \epsilon_2 < 0 \qquad \text{(A-111)}$$

$$\gamma_{12} \geq E_s,\ \gamma_{12} > 0 \quad ; \quad \gamma_{12} \leq E_s,\ \gamma_{12} < 0$$

where the intrinsic ultimate strains are as defined previously.

FAILURE INDEX OF BONDING

The failure index of bonding material is calculated as the maximum interlaminar shear stress divided by the allowable bonding stress.

A.10 CORRECTION OF OUT-OF-PLANE SHEAR STRAIN

The typical formulation for a QUAD4 type finite element follows a standard bilinear isoparametric theory, with directional reduced integration for out-of-plane shear strain. However, this formulation has been found to be inadequate when the geometry of the element is irregular, and a correction defined herein has been implemented in ASTROS to correct this problem.

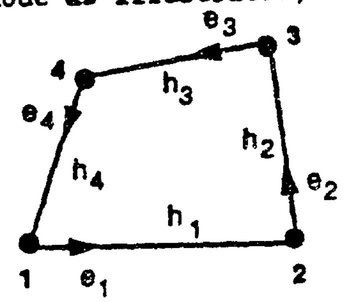
The modification is based upon the theory presented by Hughes and Tezdayar (Reference A-1), but is generalized to include non-planarity of the element, and special features to accommodate ASTROS's structure. The formulation enforces constant shear along each edge of the element, eliminating the need to perform reduced integration.

The formulation of this modification consists of establishing strain-displacement relationships in the element coordinate system. It involves six degrees of freedom (dof), the rotational part of which will be modified later to include the singularity about the normal to the mid-surface.

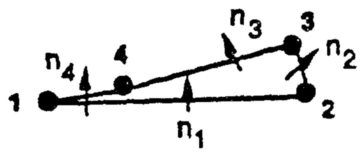
A.10.1 Geometric Variables

The following terms are defined for each edge of an irregular-shaped, non-planar element:

A Unit Normal Vector ($\vec{e}$) in the direction of the next node as illustrated;



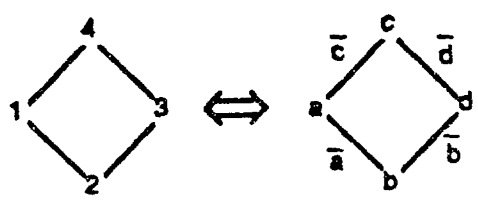
A Unit Normal Vector ($\vec{n}$) which is a normalized average of the nodal normals to the mid-surface along that edge;



Length of each edge (h_i); and cosine of the internal angle at each corner (α_i).

A.10.2 Edge Shears and Shear Vectors

Given the following numbering sequence:



At the middle of each edge, the constant shears parallel to edges $\bar{a}$, $\bar{b}$, $\bar{c}$ and $\bar{d}$, respectively, are:

$$g_{\bar{a}} = \frac{1}{h_a}\vec{n}_a \cdot (\vec{U}_b - \vec{U}_a) - \frac{1}{2}\vec{e}_a\,(\vec{\theta}_b + \vec{\theta}_a)$$

$$g_{\bar{b}} = \frac{1}{h_b}\vec{n}_b \cdot (\vec{U}_d - \vec{U}_b) - \frac{1}{2}\vec{e}_b\,(\vec{\theta}_d + \vec{\theta}_b)$$

$$g_{\bar{c}} = \frac{1}{h_c}\vec{n}_c \cdot (\vec{U}_a - \vec{U}_c) - \frac{1}{2}\vec{e}_c\,(\vec{\theta}_a + \vec{\theta}_c) \qquad \text{(A-112)}$$

$$g_{\bar{d}} = \frac{1}{h_d}\vec{n}_d \cdot (\vec{U}_c - \vec{U}_d) - \frac{1}{2}\vec{e}_d\,(\vec{\theta}_c + \vec{\theta}_d)$$

where $\vec{u}$ and $\vec{\theta}$ are the vectors of translations and rotations at each node, respectively, in the element coordinate system.

The shear vector ($\vec{\gamma}_b$) at node (b) is given by:

$$\vec{\gamma}_b = \frac{1}{1-\alpha_b^2}\,(g_{\bar{b}} + g_{\bar{a}}\alpha_b)\vec{e}_b + \frac{1}{1-\alpha_b^2}\,(g_{\bar{a}} + g_{\bar{b}}\alpha_b)\vec{e}_a \qquad \text{(A-113)}$$

or

$$\begin{aligned}
\vec{\gamma}_b = & \left[-\frac{1}{(1-\alpha_b^2)h_a}(\vec{e}_a+\alpha_b\vec{e}_b)(\vec{n}_a\cdot\vec{U}_a)\right] + \left[\frac{1}{(1-\alpha_b^2)h_a}(\vec{e}_a+\alpha_b\vec{e}_b)(\vec{n}_a\cdot\vec{U}_b)\right] \\
& - \left[\frac{1}{(1-\alpha_b^2)h_b}(\vec{e}_b+\alpha_b\vec{e}_a)(\vec{n}_b\cdot\vec{U}_b)\right] + \left[\frac{1}{(1-\alpha_b^2)h_b}(\vec{e}_b+\alpha_b\vec{e}_a)(\vec{n}_b\cdot\vec{U}_d)\right] \\
& - \left[\frac{1}{2(1-\alpha_b^2)}(\vec{e}_a+\alpha_b\vec{e}_b)(\vec{e}_a\cdot\vec{\theta}_a)\right] \qquad \text{(A-114)} \\
& - \left[\frac{1}{2(1-\alpha_b^2)}\left\{(\vec{e}_a+\alpha_b\vec{e}_b)(\vec{e}_a\cdot\vec{\theta}_b)+(\vec{e}_b+\alpha_b\vec{e}_a)(\vec{e}_b\cdot\vec{\theta}_b)\right\}\right] \\
& - \left[\frac{1}{2(1-\alpha_b^2)}(\vec{e}_b+\alpha_b\vec{e}_a)(\vec{e}_b\cdot\vec{\theta}_d)\right]
\end{aligned}$$

and similarly for the other sides, by permutations of the a, b, c and d subscripts.

A.10.3 Nodal Contributions of Shear Strain

The contribution of each node to the total shear strain ($\vec{\gamma}_T$) evaluated at an integration point is:

$$\vec{\gamma}_T = \sum_{i=1}^{4} N_i \vec{\gamma}_i \tag{A-115}$$

The "pseudo-contribution" of each edge to the total shear strain (G) has the following form:

$$\begin{aligned}
\vec{G}_a &= \frac{N_a}{1-\alpha_a^2}(\vec{e}_a + \alpha_a \vec{e}_c) + \frac{N_b}{1-\alpha_b^2}(\vec{e}_a + \alpha_b \vec{e}_b) \\
\vec{G}_b &= \frac{N_b}{1-\alpha_b^2}(\vec{e}_b + \alpha_b \vec{e}_a) + \frac{N_d}{1-\alpha_d^2}(\vec{e}_b + \alpha_d \vec{e}_d) \\
\vec{G}_c &= \frac{N_c}{1-\alpha_c^2}(\vec{e}_c + \alpha_c \vec{e}_d) + \frac{N_a}{1-\alpha_a^2}(\vec{e}_c + \alpha_a \vec{e}_a) \\
\vec{G}_d &= \frac{N_d}{1-\alpha_d^2}(\vec{e}_d + \alpha_b \vec{e}_b) + \frac{N_c}{1-\alpha_c^2}(\vec{e}_d + \alpha_c \vec{e}_c)
\end{aligned} \tag{A-116}$$

Hence, the columns of the [B] matrix partition for shear, corresponding to node b, $[BS_b]$, are:

$$\left.\begin{aligned}
\overline{(BS_{bi})} &= \frac{n_a^i}{h_a}\vec{G}_a - \frac{n_b^i}{h_b}\vec{G}_b \qquad i=1,2,3 \\
\overline{(BS_{bj})} &= \frac{e_a^i}{2}\vec{G}_a - \frac{e_b^i}{2}\vec{G}_b \qquad j=4,5,6
\end{aligned}\right\} \tag{A-117}$$

A.10.4 Transformations

The following transformations have to be performed before the preceding formulation can replace the existing [B] matrix generation for out-of-plane shear.

$$
\underset{(3x6)}{[BS_b]} = \underset{(3x3)}{[TIE]} \; \underset{(3x6)}{[\overline{BS_b}]} \begin{bmatrix} [1] & 0 \\ & [TEE] \end{bmatrix}_{(6x6)} \quad \text{(A-118)}
$$

where

[TIE] = Is the orthogonal transformation between integration points and the element coordinate system, required since all the strains are calculated in the 1 system.

[I] = Is a 3x3 identity matrix.

[TEE] = Is the 3x3 transformation which takes into account the following facts

(A) Hughes' convention for rotations is different than the one implemented in STROS; and,

(B) The rotation about the normal to the mid-surface at each grid point is singular.

If NV is the normal vector at a given grid point, then.

$$
[TEE] = \begin{bmatrix} 0 & -NV^3 & NV^2 \\ NV^3 & 0 & -NV^1 \\ -NV^1 & NV^1 & 0 \end{bmatrix} \quad \text{(A-119)}
$$

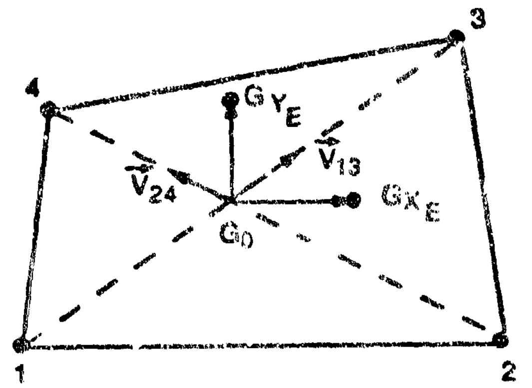


Figure A-1. Internal Element Coordinate System

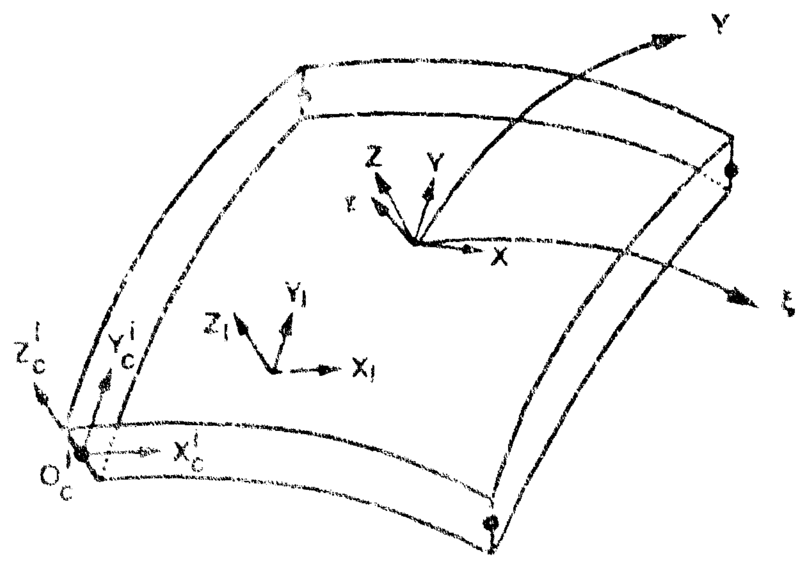


Figure A-2. Isoparametric Quadrilateral 4-Node Plate and Shell Element

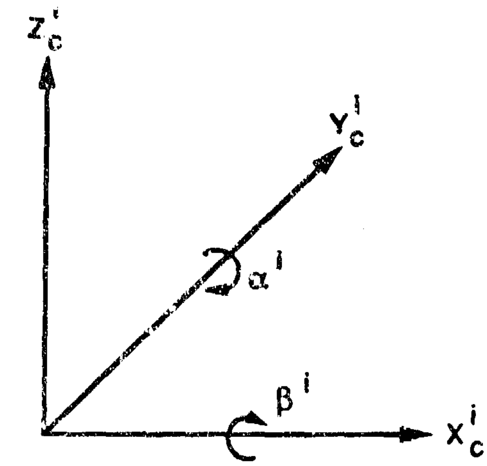


Figure A-3. Deformations at Grid Point i

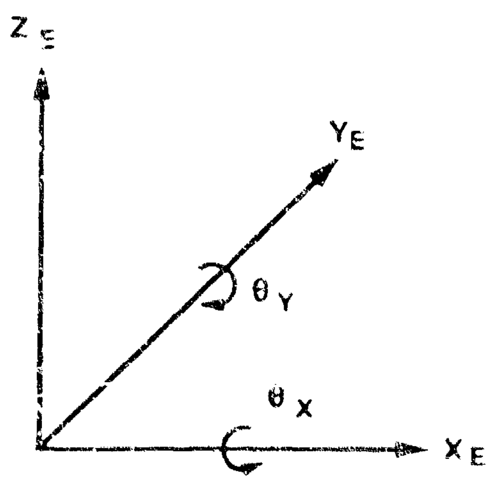


Figure A-4. Deformations in the Global Direction

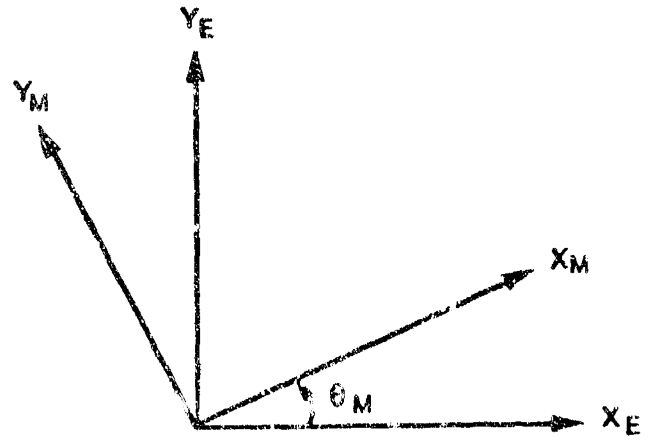


Figure A-5. Material and User Defined Element Axes

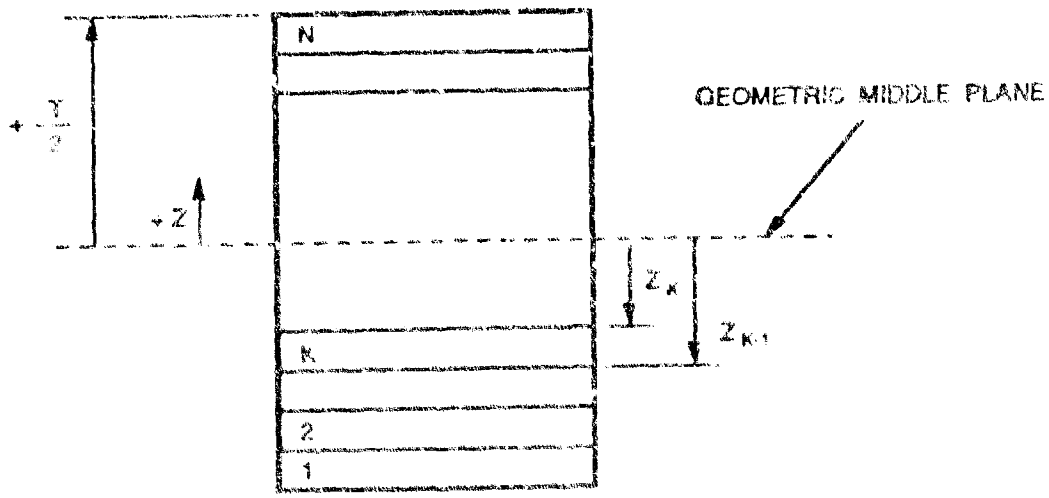


Figure A-6. Geometry of a N-Layered Element

REFERENCES

A-1. Hughes, T. J. R. and Tezduyar, T. E., "Finite Elements Based Upon Mindlin Plate Theory with Particular Reference to the Four-Node Bilinear Isoparametric Element," _Transactions of ASME, Journal of Applied Mechanics_, Volume 48, No. 3, September, 1981, pp 587-596.

APPENDIX A: GUIDELINES FOR MODELING WITH QUAD4 (TRIA3) ELEMENTS

GUIDELINES FOR MODELING WITH QUAD4 (TRIA3) ELEMENTS

ASTROS (an Automated STRuctural Optimization System) and four versions of NASTRAN (COSMIC NASTRAN, UAI NASTRAN, CSA NASTRAN and MSC NASTRAN) provide QUAD4 and TRIA3 elements for the analysis of plates. They are basically flat plate elements, but they are often used for shell structures as well as approximations. These approximations become closer to reality with a finer mesh size. Much of the discussion in these guidelines is with reference to the QUAD4 element, but comments are equally applicable to the TRIA3 element. The original QUAD4 formulation in programs ASTROS, COSMIC NASTRAN and UAI NASTRAN is just about identical, and differences (if any) are the result of subsequent revisions. MSC NASTRAN and CSA NASTRAN are different, but nevertheless all five programs give comparable results for most well posed problems. Also the input requirements and the card structure are quite compatible in all five cases with minor differences in interpretation. The purpose of these seminar notes is to explain various QUAD4 modeling options and to point-out the differences in the five programs. An explanation of the input parameters on the various cards is considered the easiest way to accomplish this objective.

The QUAD4 is one of the most extensively used elements in NASTRAN as well as ASTROS. It is a very versatile element and can be used to model a variety of plate simulations such as (see Fig. 1).

a. Membrane (inplane loading) behavior
b. Bending (out of plane loading) behavior
c. Membrane-bending (uncoupled)
d. Membrane-bending (coupled-linear)
e. Laminated plates
f. Layered composites
g. Sandwich plates with metal face sheets
h. Sandwich plates with layered composite face sheets
i. Isotropic materials
j. Anisotropic (including orthotropic) materials

Application of the QUAD4 is often confusing becaus of the many options available for its use.

There are five cards which describe the input parameters for the QUAD4. They describe its geometry and properties along with some auxiliary information.

<u>Geometry and Property Cards</u>

CQUAD4 - Connection card
PSHELL - Property card for homogeneous and sandwich plates

PCOMP
or
PCOMP1* - Property cards for laminated or layered plates
or
PCOMP2*

*Not applicable to MSC NASTRAN

Material Cards

MAT1 - Isotropic materials
MAT2 - Anisotropic materials
MAT8 - Orthotropic materials
PLOAD4 - Pressure load definition on the QUAD4 element

The property cards PCOMP1 and PCOMP2 are not applicable to MSC NASTRAN. For a given element either the PSHELL or PCOMP card is applicable but not both. PSHELL cards are for homogeneous (nonlaminated) and sandwich plates with nonlayered face sheets. PCOMP cards are for laminated (layered) plates. In the case of sandwich plates with layered face sheets the honeycomb (sandwich) core will be treated as a laminate or layer.

A supplementary explanation of the parameters on each of these cards should aid in understanding the modeling nuances of the element.

Notes on the CQUAD4

The format of the CQUAD4 is the same for all the NASTRANS and ASTROS with the exception of an additional parameter "TMAX" (field 3 on the continuation card) in ASTROS. "TMAX" is the maximum allowable thickness of the plate, applicable only in optimization.

The definitions of the parameters in fields 2 to 7 are self explanatory and need no further clarification. Similarly no additional explanation is necessary for the thickness parameters specified in fields 4 to 7 on the continuation card. However, the parameters TM (THETA) and ZOFF need a supplementary explanation or caution.

Parameter TM (THETA)

The parameter TM defines the material property orientation. There are two options for this definition.

Option 1:

Define the angle between the side of the element (connecting G1 and G2) and the material axis. This is the least desirable option. It is prone to errors, because every time the sequence of the element connection changes, the angle must be changed. Also in a complex three dimensional model it is not easy to determine this angle without writing a preprocessor.

Option 2:

The integer option is preferable. An integer in field 8 refers to a separate coordinate system for defining the orientation of the material axis of the element. The material property definition is now independent of the connection sequence. The new coordinate system can be defined with a CORDZR card.

Offset Parameter ZO (ZOFFS, ZOFF)

The offset parameter provision in the QUAD4 element constitutes a significant enhancement for plate elements. Before the QUAD4 the grid points of the structure could only be defined on the mid-surface of the plate elements. The Bar (beam or bend) was the only other element with an offset capability. However, some of the mass elements have the offset capability.

The offset, ZO, is shown for various cases in Fig. 3. Note the distinction between the grid point surface and mid-surface of the element. The definition of the offset ZO on the CQUAD4 is the same in all four NASTRANS and ASTROS. The offset implementation in COSMIC NASTRAN and ASTROS appears to give more consistent results than MSC and CSA NASTRAN. See Reference A1 for results on the benchmarking of offsets.

Notes on PSHELL

PSHELL or PCOMP are the property cards referenced on the CQUAD4 (in field 3). The PSHELL is to be used when the plate is not laminated (or layered), while the PCOMP is for laminated plates. Only one of these is applicable for a given element. A preprocessor in NASTRAN (ASTROS) generates equivalent PSHELL cards from the PCOMP cards before proceeding to the solution. NASTRAN (ASTROS) provides versatility to the QUAD4 element through the PSHELL card. It allows the modeling of membrane (inplane), bending, shear and membrane-bending coupling behavior. Fig. 2 illustrates key features of the elements described on the PSHELL card. It is a sandwich plate with two face sheets separated by a honeycomb core.

The first two fields of the PSHELL card are for the name and property identification called from the CQUAD4. The third field, MID1, is the material identification number for the face sheets in membrane behavior. The parameter T is the total thickness of the two face sheets. MID2 is the material identification number for bending behavior, MID3 for shear and MID4 for membrane-bending coupling. There are two types of membrane bending coupling. The coupling resulting from asymmetry in plate construction (non-symmetric laminates) is called linear coupling. Nonlinear coupling, on the other hand, is a result of the interaction of internal forces such as inplane and out of plane (beam-column effect) forces. The latter coupling can be accounted for only in differential stiffness and/or buckling analysis. The parameter $12I/T^3$ (field 6) can be calculated by using the following definition for I.

$$I=2\left[\frac{1}{12}\left(\frac{T}{2}\right)^3+\frac{T}{2}\left(\frac{TS}{2}+\frac{T}{4}\right)^2\right]$$

I is basically the moment of inertia of the face sheets about the neutral axis (centroidal). It is assumed that the face sheets are symmetric about the neutral axis. If they are not, the moment of inertia about the neutral axis can be calculated. For solid plates this parameter is simply 1.0

The definition of the parameter TS/T is obvious from the figure.

No further explanation is necessary for the parameters in the next three fields, NSM, Z1 and Z2.

The parameters MCSID and SCSID (not available in MSC and CSA NASTRAN) refer to the material coordinate system. As stated in the description of the card CQUAD4 there are two options for this definition. By leaving the field blank or a real value the first option is invoked. In this option the parameter represents the angle between the side of the element connecting the grid points G1 and G2 and the material axis. The second option is an integer which refers to a coordinate system defined on a COORD-card. The second option is the most desirable because the grid point sequence on the CQUAD4 card does not affect the material axis.

The offset parameter ZO is the same as defined on the CQUAD4 (See Fig. 3). An important point to note is that there is no provision for the offset definition on the PSHELL card in MSC and CSA NASTRAN. There is some advantage in having this option on the PSHELL, because when the number of PSHELL cards is significantly fewer than the number of CQUAD4 cards, this parameter need not be repeated on all the CQUAD4 cards. The entry on CQUAD4, however, overrides that on the PSHELL card.

The PSHELL card provides the facility to model homogeneous as well as sandwich plates. However, the face sheets of the sandwich plates are assumed to be homogeneous (isotropic, orthotropic or anisotropic) plates. A discussion of sandwich plates with face sheets made of layered composites is differed until the PCOMP cards description. The minimum thickness parameter TMIN is applicable only in ASTROS optimization.

Before leaving this discussion, it is worth pointing out some anomalies (idiosyncrasies) (as they exist at present, Feb 1993) in the application of the PSHELL card in various versions of NASTRAN (ASTROS).

Specifying MID1 and leaving the remaining three material identifications blank simulates the membrane behavior in all five programs with little or no differences to point out.

Specifying MID2 only invokes bending behavior only (as it should be) in MSC NASTRAN. It does not compute shear deformation. CSA NASTRAN on the other hand includes shear deformation, ostensibly with the material properties invoked by MID2. ASTROS and COSMIC NASTRAN go even further by including membrane, bending and shear deformations even though only MID2 is specified. Membrane and bending behavior are computed by the material properties called from MID2. This is not so bad, because these two behaviors are generally uncoupled. The most important point to note is that ASTROS (COSMIC NASTRAN) computes the shear deformation by assuming a material infinitely stiff in transverse shear when the MID3 field is blank. These results are, in general, not acceptable. The easiest way to avoid shear stiffness over-estimation at present is not to leave MID3 blank when MID2 is specified. See results of the examples at the end of this Appendix. Future versions of ASTROS and COSMIC NASTRAN will uncouple these computations.

Notes on PCOMP, PCOMP1, PCOMP2

The purpose of PCOMP, PCOMP1 and PCOMP2 is to define element property parameters in modeling laminated plates including layered (fiber reinforced) composites. All three cards serve the same purpose except the options are different. If the layers are made of different materials and the thicknesses of the layers are all different, then the PCOMP card is appropriate. If all the layers are made of the same material and thickness, then PCOMP1 is appropriate. If the material is the same, but the thicknesses are different, then PCOMP2 is appropriate. The first two fields on the PCOMP cards need no further explanation.

Parameter ZØ

The parameter ZØ refers to the distance from the grid point surface to the bottom of the plate. The plate bottom surface is defined in Fig. 4. It is the reference surface from which the stacking sequence of the laminates is defined. The parameters ZOFF defined on the (QUAD4 and PSHELL) are a source of confusion sometimes. However, figures 3 and 4 should provide better clarification.

Parameter SBOND

The bonding material shear stress is indirectly related to the interlaminar shear and its value is generally empirical. A value of 400 to 500 psi for SBOND appears to be reasonable in the absence of a value obtained from experiments. Any approximation of this parameter will not affect the analysis results. It affects only the failure theory which is basically a postprocessing function.

Parameters FT (Field 6)

This parameter simply identifies the desired failure theory. The five failure theories are discussed in detail in the theoretical section of the QUAD4 seminar notes. The possible values of FT are:

"HILL" for the Hill Theory
"HOFF" for the Hoffman Theory
"TSAI" for the Tsai-Wu Theory
"STRESS" for the Maximum Stress Theory
"STRAIN" for the Maximum Strain Theory

Parameter LOPT

This parameter description needs no further explanation than what is given in the PCOMP card descriptions. It should be pointed out, however, that no parameters are in fields 7 and 8 in COSMIC NASTRAN, while MSC and CSA NASTRAN define "TREF," a reference temperature for thermal stress analysis and "GE" the material damping coefficient for dynamic analysis.

Parameters MIDi, Ti, THi, and SOUTi

These parameters pertain to the ith layer. MID1 is the material identification number of the first layer. The layer count goes up from the bottom surface of the plate. For the definition of the bottom surface see Fig. 4 for the definition of ZØ. The MIDi refers to one of three material cards: MAT1 for isotropic materials, MAT2 for anisotropic materials and MAT8 for orthotropic materials. The parameter T1 defines the thickness of the first layer and TH1 refers to the orientation of the material axis with reference to the material axis defined on the CQUAD4. SOUT1 is the stress output parameter. Then the parameters are repeated for all the layers unless the symmetry option is used under the parameter LOPT. If any MIDi, Ti or THi are blank, then the last non-blank values specified for each will be used.

Material Cards

Isotropic & Anisotropic

The parameters on MAT1 and MAT2 are self explanatory from the card descriptions.

Orthotropic Material MAT8

Most of the parameters on MAT8 are self explanatory with the exceptions of G1Z and G2Z (fields 7 and 8). When these parameters are left blank, MSC NASTRAN and CSA NASTRAN do not calculate the transverse shear deformation in plate bending problems. ASTROS and COSMIC NASTRAN, on the other hand, assume that the material is infinitely stiff in transverse shear, and thus overestimate the stiffness of the element. To avoid such overestimation and to obtain comparable results to the other NASTRANS, transverse shear values have to be provided. Values of about two or three orders of magnitude less than the modulus of elasticity of the material are recommended.

These guidelines and the accompanying examples should clarify most of the questions arising in the use of the QUAD4 and TRIA3 elements.

REFERENCE

1. Pitrof, Stephen M. and Venkayya, Vipperla B., Benchmarking the QUAD4/TRIA3 Element, Twenty-first NASTRAN User's Colloquium, Tampa FL, April 1993.

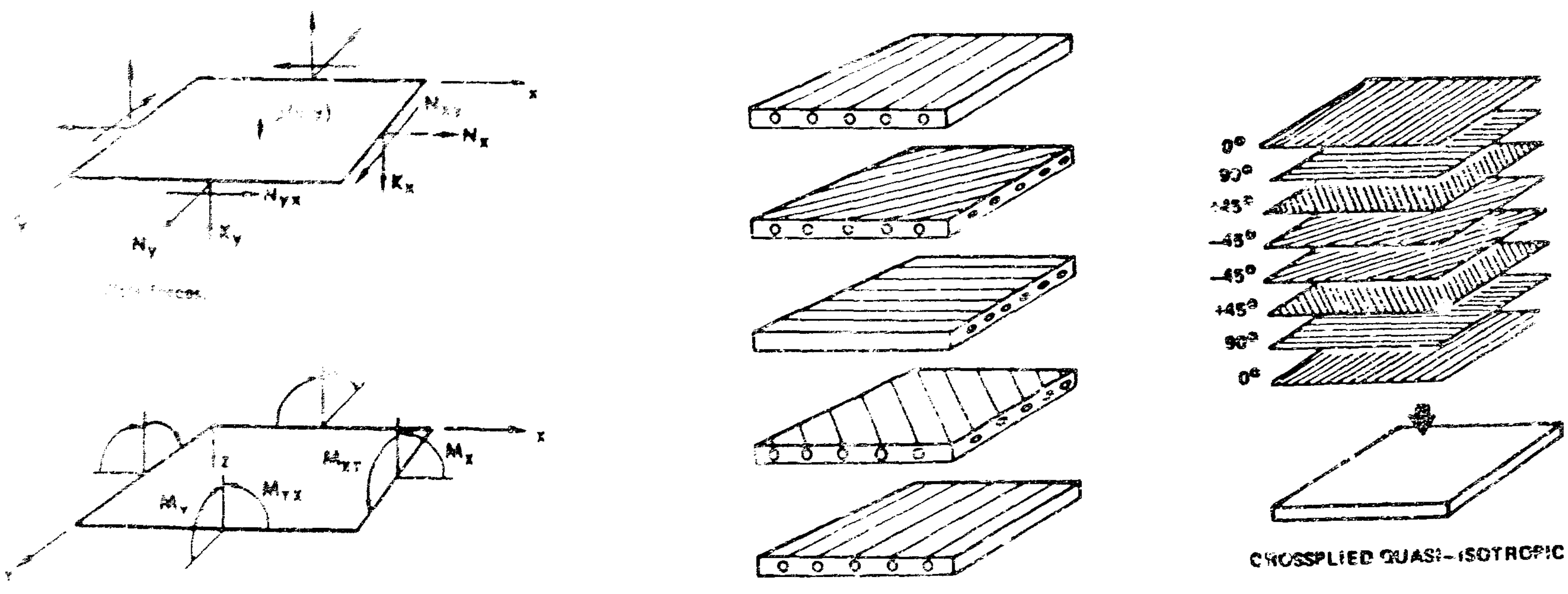


Plate moments.

Laminate construction.

Figure 1

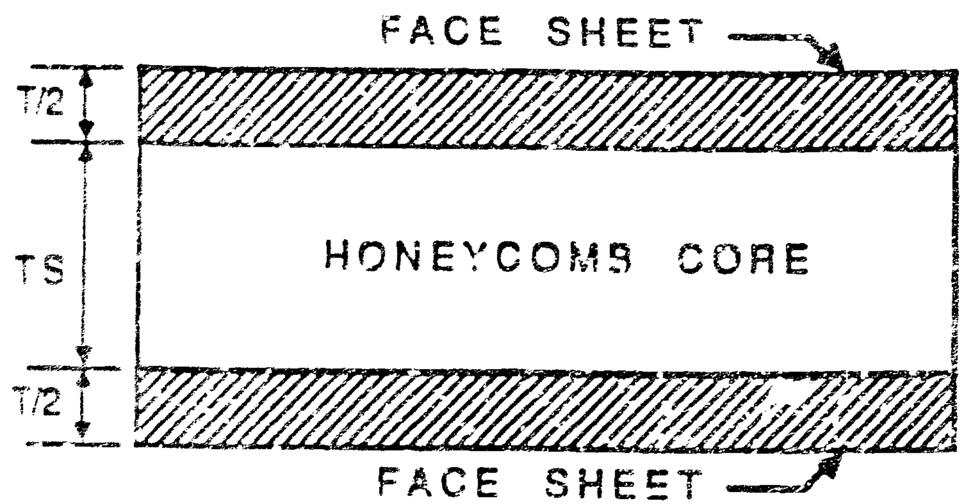


Figure 2

QUAD4 - OFFSET DEFINITION

(CQUAD4 PSHELL)

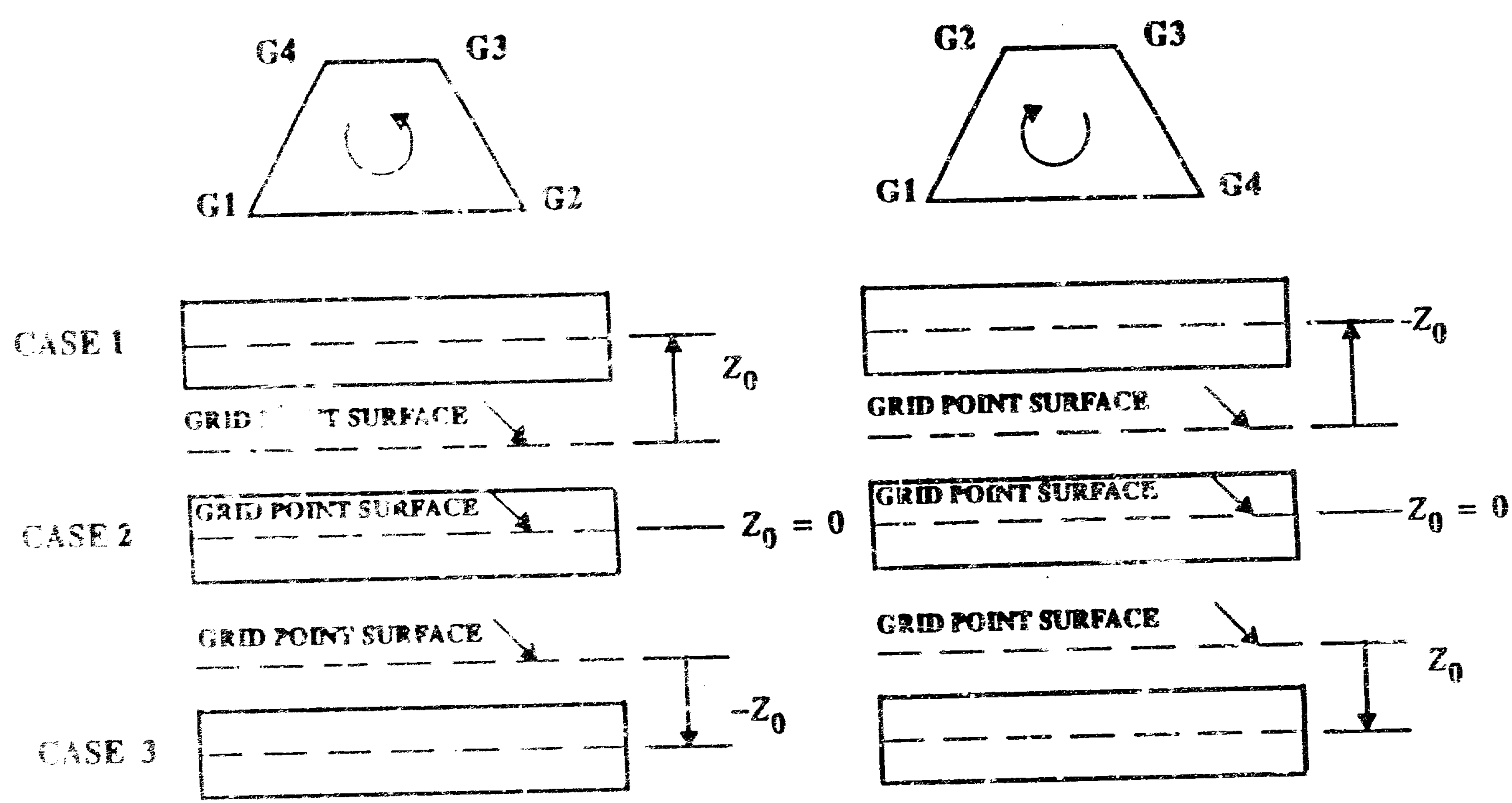


Figure 3

QUAD4 - OFFSET DEFINITION

(PCOMP PCOMP1 PCOMP2)

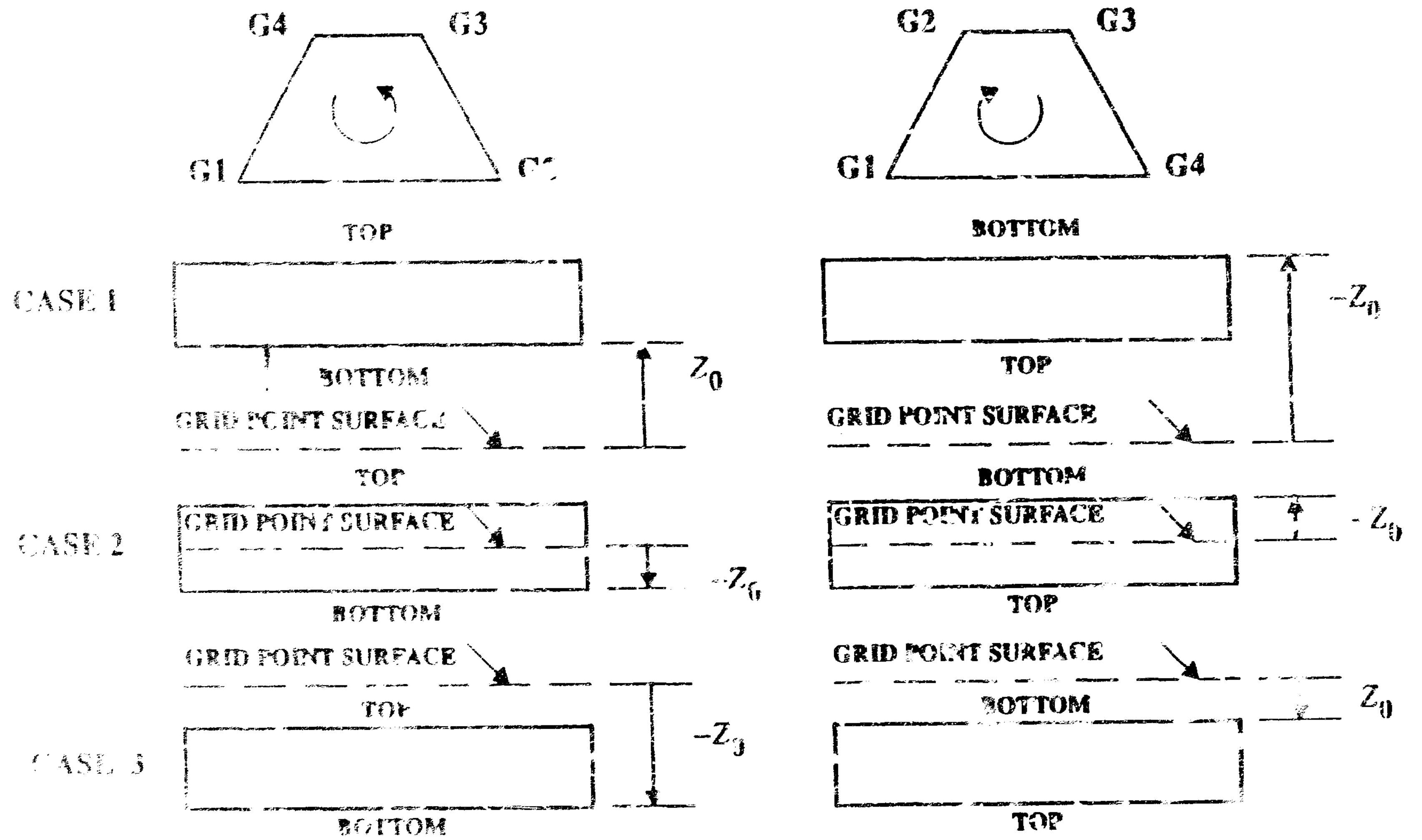


Figure 4

INPUT IS PROVIDED

PROBLEM #5

RECTANGULAR PLATE

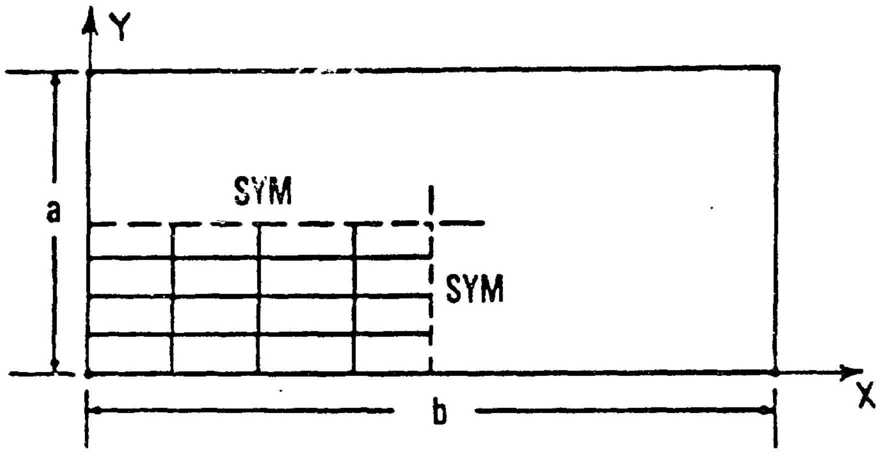


FIGURE 5

A finite element model of 1/4 of a rectangular plate is shown in Fig. 5. The length of the plate is 2 or 10, the width is 2, i.e. Aspect Ratios (AR) 1.0 and 5.0, and the thickness is .001. The material properties are given as E=1.7472x10 and ν=0.3. The plate is subjected to two loading conditions and boundary conditions for each aspect ratio as follows:

CASE 1: Clamped Supports. Concentrated load of $P = -4.0 \times 10^{-4}$ at the center of the plate.

CASE 2: Simple Supports. Uniform pressure load of $q=10^{-4}$ over the plate.

Convergence is studied by varying the mesh size. Input data is given for a 6x6 mesh. Theoretical results for the lateral displacement at the center of the plate are given in Table 2.

CASE 1		CASE 2	
AR = 1.0	AR = 5.0	AR = 1.0	AR = 5.0
5.60	7.23	4.062	12.97

TABLE 2

Example A4: The plate is modeled as a sandwich plate with composite face sheets and a honeycomb core. The thickness of the core is 2in. Two cases are considered. In Case 1 the MAT8 entries G1Z and G2Z are not specified. In Case 2 G1Z and G2Z are given the value 4.0×10^5 psi.

Z DISPLACEMENT ($x10^{-3}$) AT THE CENTER OF THE PLATE

NASTRAN	MID2 ONLY	MID1, MID2 AND MID3 SPECIFIED
COSMIC	-7.324	7.68[illegible]
MSC	-7.[illegible]43	-7.683
CSA	-7.63[illegible]	-7.6[illegible]
ASTROS	-7.322	-7.680

EXAMPLE A1: QUAD4 - MID SPECIFICATIONS
Metal Homogeneous Aluminum

Z DISPLACEMENT AT THE CENTER OF THE PLATE

NASTRAN	FACE SHEETS AND CORE HAVE THE SAME MATERIAL PROP	CORE MATERIAL $E= 2.5 X 10^4$, $G=1.0 X 10^4$	CORE MATERIAL $G=1.0 X 10^4$
COSMIC	-.000194	-.0150	-.0150
MSC	-.000193	-.0150	-.0150
CSA	-.000192	-.0150	-.0150
ASTROS	-.000193	-.0150	-.0150

EXAMPLE A2: QUAD4 SANDWICH - HONEYCOMB PROPERTIES
Sandwich Plate Isotropic Face Sheets

Z DISPLACEMENT ($x10^{-2}$) AT THE CENTER OF THE PLATE

NASTRAN	NO G1Z, G2Z	G1Z = G2Z = 4.0×10^5
COSMIC	-.803	-1.071
MSC	-.838	-1.074
CSA	-.945	-1.029
ASTROS	-.831	-1.071

EXAMPLE A3: QUAD4 - SHEAR - G1Z, G2Z SPECIFIED
Composite Solid Plate

Z DISPLACEMENT ($x10^{-3}$) AT THE CENTER OF THE PLATE

NASTRAN	NO G1Z, G2Z	G1Z = G2Z = 4.0×10^5
COSMIC	-.199	-2.691
MSC	-6.464	-6.526
CSA	-5.067	-5.109
ASTROS	-.173	-6.531

EXAMPLE A4: QUAD4 - SANDWICH - COMPOSITE FACE SHEETS
Composite Sandwich Plate with Honeycomb Core

APPENDIX B: SAMPLE PROBLEMS

QUAD4 SEMINAR

APPENDIX B

SAMPLE PROBLEMS

* Problems 1 through 7 reference isotropic material and are defined in the MSC/NASTRAN APPLICATION MANUAL, SECTION 5.

+ Problems 8 through 12 are provided by UAI/NASTRAN.

B.1 PROBLEM DESCRIPTIONS

INPUT IS PROVIDED

PROBLEM #1

PATCH TEST

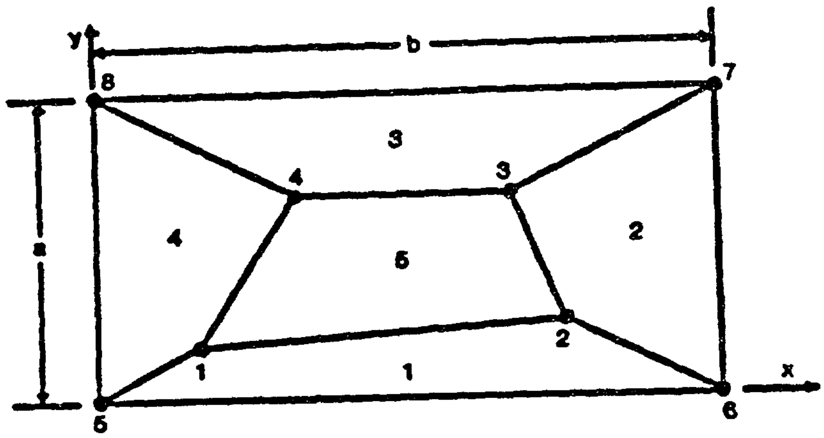


FIGURE 1

A model of a patch test for plates is shown in Fig. 1. The length of the plate is .24, the width is .12, and the thickness is .001. The location of the inner nodes is given in Table 1. The material properties are given as $E=1.0 \times 10^6$ and $\nu=0.25$. Displacement boundary conditions are specified for the following cases:

CASE 1. Membrane Plate

$$u = 10^{-3}(x+y/2)$$

$$v = 10^{-3}(y+x/2)$$

CASE 2. Bending Plate

$$w = 10^{-3}(x^2+xy+y^2)/2$$

$$\theta_x = \frac{\partial w}{\partial y} = 10^{-3}(y+x/2)$$

$$\theta_y = -\frac{\partial w}{\partial x} = 10^{-3}(-x-y/2)$$

The theoretical solution for Case 1 is given by

$$\varepsilon_x = \varepsilon_y = \gamma = 10^{-3}; \ \sigma_x = \sigma_y = 1333.; \ \tau_{xy} = 400.$$

The theoretical solution for Case 2 is given by

Bending moments per unit length:

$$m_x = m_y = 1.111 \times 10^{-7}, \; m_{xy} = 10^{-7}$$

Surface stresses:

$$\sigma_x = \sigma_y = \pm .667; \; \tau_{xy} = \pm .200$$

LOCATION OF INNER NODES		
NODE	X	Y
1	.04	.02
2	.18	.03
3	.16	.08
4	.08	.08

TABLE 1

INPUT IS PROVIDED

PROBLEM #2

STRAIGHT CANTILEVERED BEAM

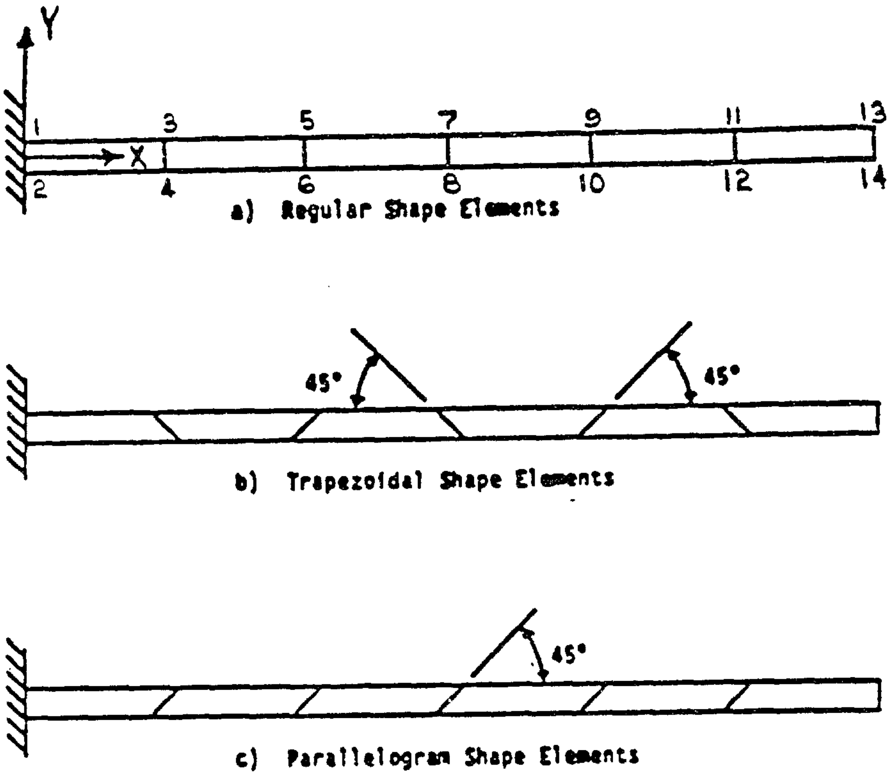


FIGURE 2

A finite element model of a straight cantilevered beam with rectangular, trapezoidal and parallelogram shape elements is shown in Fig. 2 (plane view). The length of the beam is 6, the width is 0.2 and the depth is 0.1. The beam has material properties $E=1.0x10^7$ and $\nu=.30$. All the elements have equal volume. The beam is subjected to 4 loading conditions as follows:

CASE 1: A unit force is applied at the tip in the X direction. (Extension)

CASE 2: A unit force is applied at the tip in the Y direction. (In-plane shear)

CASE 3: A unit force is applied at the tip in the Z direction. (Out-of-plane shear)

CASE 4: A unit force is applied at the tip in the $\pm Z$ direction. (Twist)

The theoretical solution for the displacement at the tip in the direction of the load for Case 1 is $3.0x10^{-5}$, for Case 2 0.1081, for Case 3 0.4321 and for Case 4 $.03208x10^{-2}$.

INPUT IS PROVIDED

PROBLEM #3

CURVED BEAM

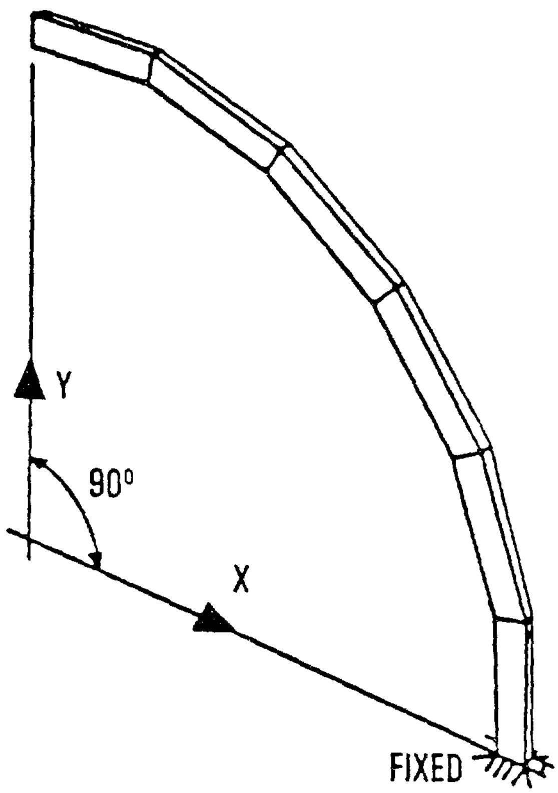


FIGURE 3

A finite element model of a curved cantilevered beam is shown in Fig. 3. The inner radius is 4.12, the outer radius is 4.32, the arc is 90°, and the thickness is 0.1. The beam has material properties $E=1.0\times10^7$ and $\nu=0.25$. The beam is subjected to two loading conditions as follows:

CASE 1: A unit force is applied at the tip in the +Y direction. (In-plane shear)

CASE 2: A unit force is applied at the tip in the +Z direction. (Out-of-plane shear)

The theoretical solution for the deflection at the tip in the direction of the load for Case 1 is .08734 and for Case 2 is .5022.

INPUT IS PROVIDED

PROBLEM #4

TWISTED BEAM

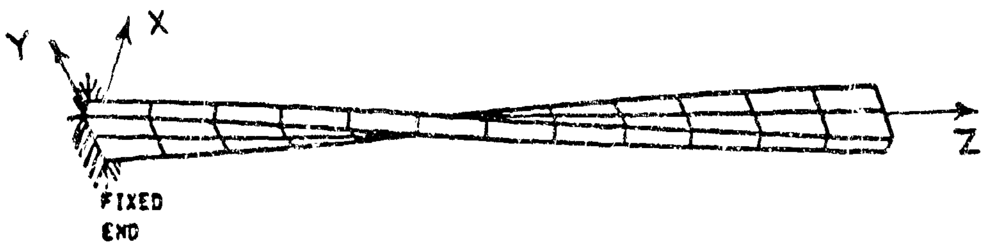


FIGURE 4

A finite element model of a twisted beam is shown in Fig. 4. The length of the beam is 12, the width is 1.1 and the depth is .32. The beam is twisted 90^{0} from root to tip. The material properties are given as $E=29.0 \times 10^{6}$ and $\nu=0.22$, and the beam is subjected to two loading conditions as follows:

CASE 1: A unit force is applied at the tip in the +X direction. (In-plane shear)

CASE 2: A unit force is applied at the tip in the -Y direction. (Out-of-plane shear)

The theoretical solution for the deflection at the tip in the direction of the load for Case 1 is .005424 and for Case 2 is .001754.

INPUT IS PROVIDED

PROBLEM #5

RECTANGULAR PLATE

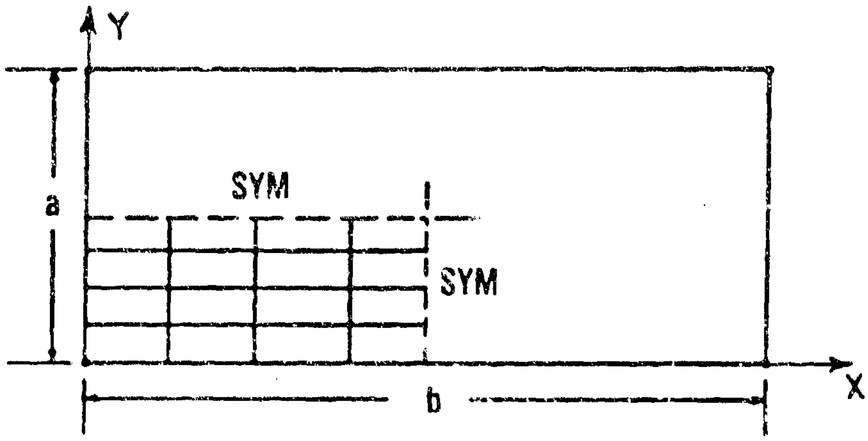


FIGURE 5

A finite element model of 1/4 of a rectangular plate is shown in Fig. 5. The length of the plate is 2 or 10, the width is 2, i.e. Aspect Ratios (AR) 1.0 and 5.0, and the thickness is .001. The material properties are given as E=1.7472x10 and ν=0.3. The plate is subjected to two loading conditions and boundary conditions for each aspect ratio as follows:

CASE 1: Clamped Supports. Concentrated load of $P = -4.0 \times 10^{-4}$ at the center of the plate.

CASE 2: Simple Supports. Uniform pressure load of $q=10^{-4}$ over the plate.

Convergence is studied by varying the mesh size. Input data is given for a 6x6 mesh. Theoretical results for the lateral displacement at the center of the plate are given in Table 2.

CASE 1		CASE 2	
AR = 1.0	AR = 5.0	AR = 1.0	AR = 5.0
5.60	7.23	4.062	12.97

TABLE 2

INPUT IS PROVIDED

PROBLEM 6

SCORDELIS - LO ROOF

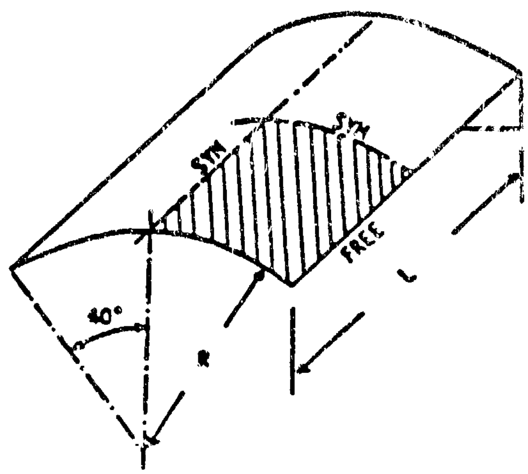


FIGURE 6

A model of a Scordelis-Lo Roof i.e. a singly curved shell, is shown in Fig. 6. The roof has a radius of 25', a length of 50', and a thickness of 0.25'. The material properties are given as $E=4.32 \times 10^8$ lbs/ft^2 and $\nu=0.0$. The roof is loaded by its own weight, and the weight of the roof is 90 lbs/ft^2. Only 1/4 of the roof is modeled. Symmetry boundary conditions are imposed on the interior edges and $U_x=U_z=0$ on the curved edges. Convergence is studied by varying the mesh size. Input data is given for an 8x8 mesh. The theoretical solution for the midside vertical displacement is .3086'. A value of .3024' was used for normalization of the results.

Reference: Zienkiewicz, O.C., The Finite Element Method, Third Edition, McGraw-Hill Book Co, (UK) Limited, pp 349-351.

INPUT AND OUTPUT ARE PROVIDED

PROBLEM #7

SPHERICAL SHELL

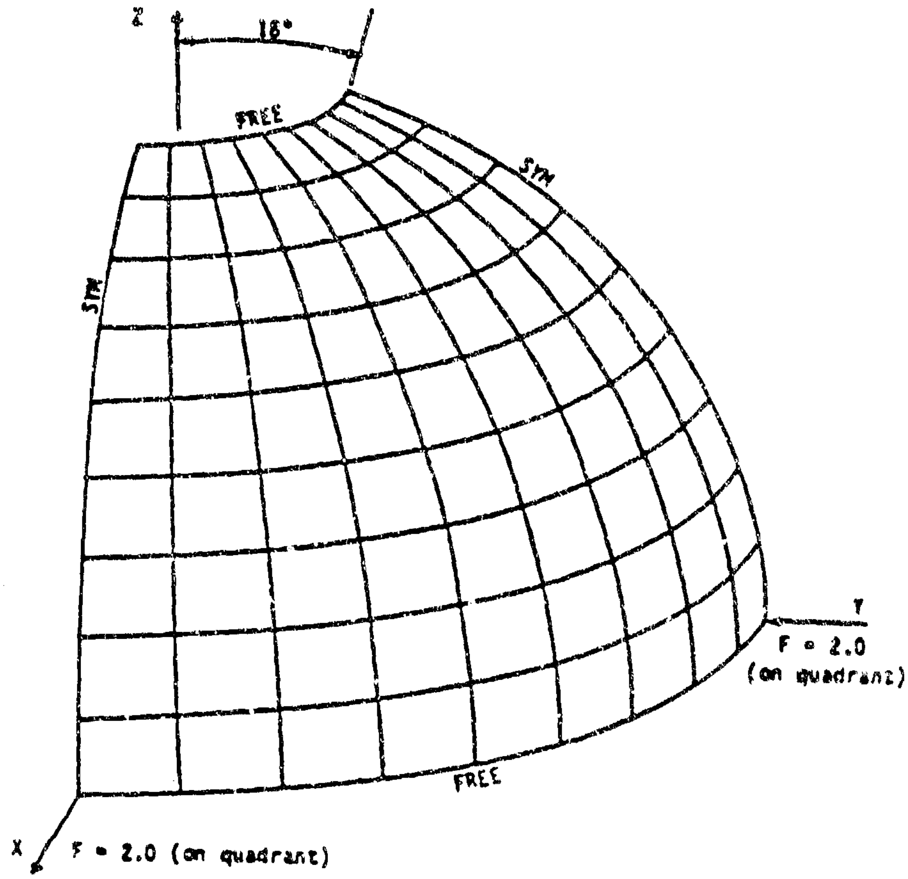


FIGURE 7

A model of a spherical shell, i.e. a doubly-curved shell, is shown in Fig. 7. The shell has a radius of 10 and a thickness of 0.4. The material properties are given as $E=6.825\times10^7$ and $\nu=0.3$. The shell is subjected to concentrated forces as shown in Fig. 7. Only 1/4 of the shell is modeled and symmetry boundary conditions are imposed on two sides. In addition the * node is constrained in the Z direction. Convergence is studied by varying the mesh size. Input and outut are given for an 8x8 mesh. A theoretical lower bound for the radial deflection at the center in the case where the hole at the center is not present is .0924. A value of .0940 was used for normalization of the results.

Reference: Morley, L.S.D., and A.J. Morris, Conflict Between Finite Elements and Shell Theory, Royal Aircraft Establishment Report, London, 1978.

INPUT IS PROVIDED

PROBLEM #8

REGULAR SYMMETRIC CROSS-PLY LAMINATE

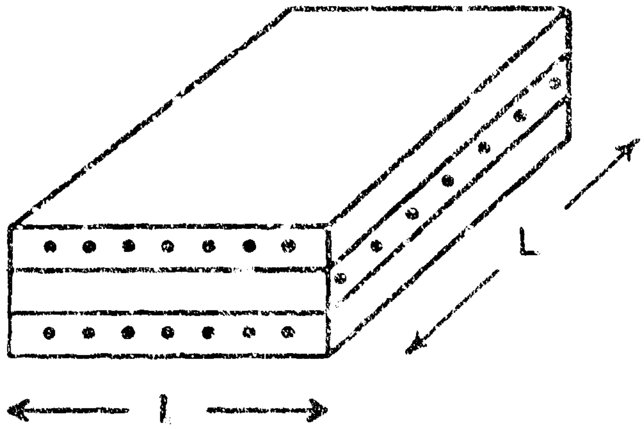


FIGURE 8

A composite square plate of length 5 modeled as a symmetric cross-ply laminate [0, 90, 0] with four elements is shown in Fig. 8. The thickness of each ply is .02222. The material properties are given as $E_1=2.0\times10^7$, $E_2=5.0\times10^5$, $\nu_{12}=0.25$ and $G_{12}=2.5\times10^5$ and are the same for each ply. Three corners of the plate are pinned and a unit force in the -Z direction is applied at the free corner to simulate a pure twist loading. The theoretical solution for the Z deflection at the free corner is -3.750×10^{-3}. Theoretical results are also given for τ for the element containing the free corner in Table 3.

LAYER	τ
1	-50.0
2	0.0
3	50.0

TABLE 3

INPUT IS PROVIDED

PROBLEM #9

REGULAR SYMMETRIC CROSS-PLY LAMINATE

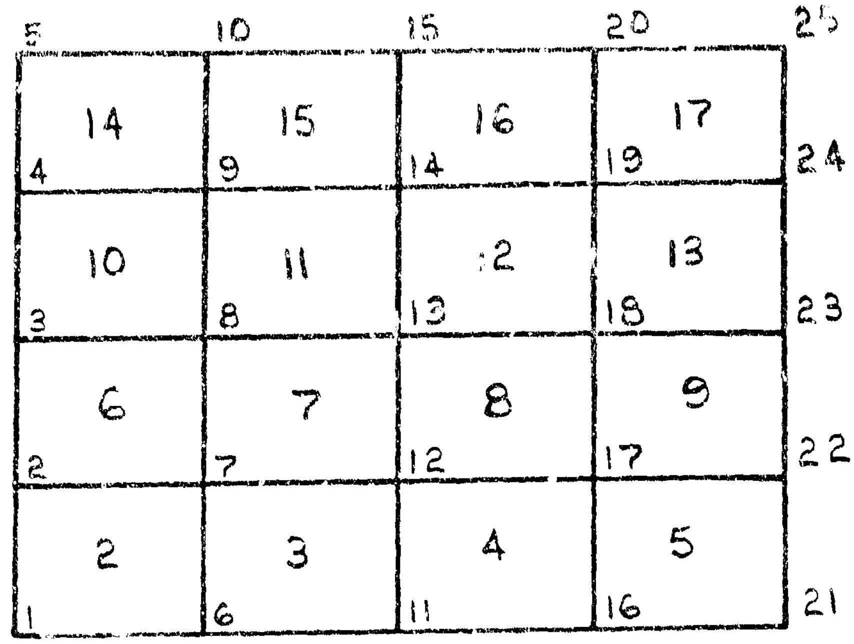


FIGURE 9

A quarter model of a composite square plate modeled as a symmetric cross-ply laminate is shown in Fig. 9. The length of each side is 1.0, and the thickness of each ply is .000666. The material properties are given as $E_1=2.0x10^7$, $E_2=5.0x10^5$, $\nu_{12}=0.25$ and $G_{12}=2.5x10^5$ and are the same for each ply. The full plate is simply supported and is subjected to a uniform pressure load of $-1.0x10^{-4}$. The finite element model contains 25 nodes and 16 elements. The theoretical solution for the Z deflection at Grid 25 (center of the plate) is $-1.836x10^{-3}$. Theoretical results are also given for the stresses in layers 1 and 3 in element 17 in Table 4.

σ_1	σ_2	τ_{12}
58.6	1.8	-.06

TABLE 4

PROBLEM #10

COMPOSITE OPEN TUBE

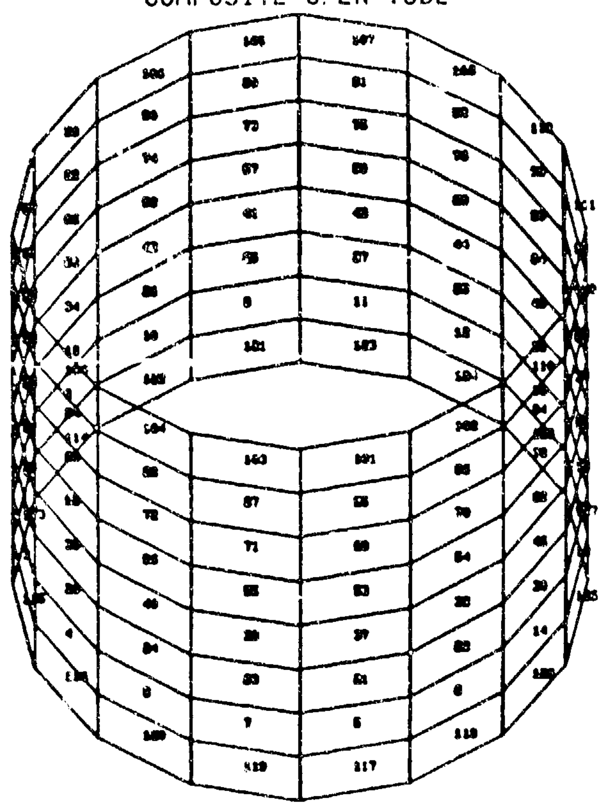


FIGURE 10

A finite element model of a composite open tube modeled with the symmetric lay-up [45, -45, 0, 90, 90, 0, -45, 45] is shown in Fig. 10. The model contains 144 nodes and 128 elements. The length of the tube is 80, the radius is 50, and the thickness of each layer is .24. The material properties are given as $E_1=73.8\times10^3$, $E_2=3.75\times10^3$, $\nu_{12}=0.4$, and $G_{12}=1.74\times10^3$. The tube is subjected to a uniform pressure load of 10.5. The theoretical solution for the hoop loading, FY, for element 8 is 525. Results from MSC/NASTRAN are given in Table 5 for the layer stresses in element 8.

LAYER	σ_1	σ_2	τ_{12}
1	2.519E2	1.740E1	2.273E1
2	2.494E2	1.748E1	-2.273E1
3	-2.257E2	3.288E1	1.108E-2
4	7.268E2	2.651E0	2.221E-2
5	7.269E2	2.657E0	5.551E-2
6	-2.255E2	3.231E1	-8.881E-2
7	2.535E2	1.741E1	-2.274E1
8	2.478E2	1.760E1	2.274E1

TABLE 5

INPUT IS PROVIDED

PROBLEM #11

STRAIGHT BEAM TEST

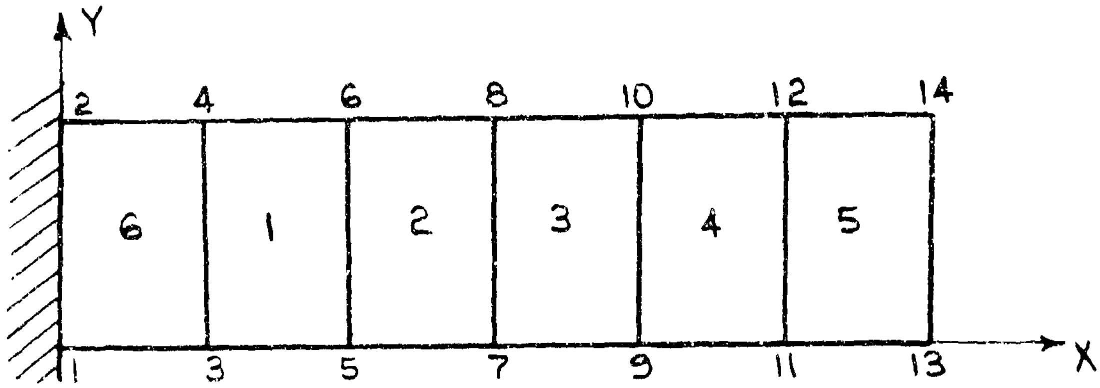


FIGURE 11

A finite element model of a cantilevered beam modeled as a laminate configuration [0, 0, 0, 0] in a simulation of equivalent isotropic properties is shown in Fig. 11. The length of the beam is 6, and the thickness of each layer is .25. The material properties are given as $E=10.0\times10^6$ and $\nu=.3$. The beam is subjected to two loading conditions as follows:

CASE 1: A unit force is applied at the tip in the X direction. (Extension)

CASE 2: A unit force is applied at the tip in the Z direction.

For Case 1 the theoretical solution for the X deflection at Grids 13 and 14 is 3.0×10^{-5}. For Case 2 the theoretical solution for the Z deflection at Grids 13 and 14 is .4320. Theoretical results are given for the bending moment distribution from the free end to the cantilevered end in Table 6.

ELEMENT NO.	M_x
5	2.50
4	7.50
3	12.50
2	17.50
1	22.50
6	27.50

TABLE 6

For Case 2 results from MSC/NASTRAN are given in Table 7 for the direct layer bending stress in element 6.

LAYER NO.	σ_1
1	1.238E4
2	4.126E3
3	-4.126E3
4	-1.238E4

TABLE 7

INPUT AND OUTPUT ARE PROVIDED

PROBLEM #12

COMPOSITE SHELL ROOF

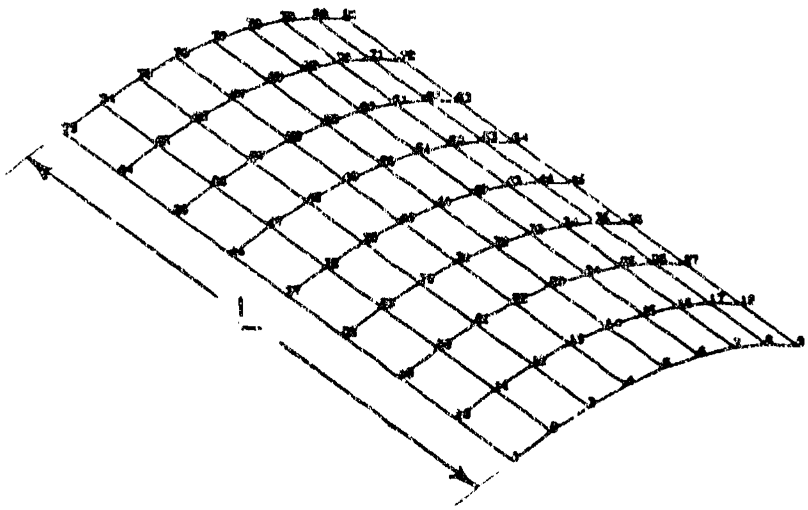


FIGURE 12

A finite element model of a composite shell roof modeled with the symmetric lay-up [45, -45, 15, -15, -15, 15, -45, 45] is shown in Fig. 12. The length and radius of the shell are 25, and the thickness of each layer is .03125. The material properties are given as $E_1=2.0\times10^8$, $E_2=0.5\times10^7$, $\nu_{12}=0.25$, $G_{12}=2.5\times10^6$, and $G_{13}=G_{23}=2.5\times10^6$. The shell is subjected to a uniform pressure of 90.0. Results from MSC/NASTRAN are given in Table 8 for the radial deflection at selected nodes.

GRID	T1
34	-1.0662
35	-1.3441
36	-1.6074
43	-1.3267
44	-1.6739
45	-2.0079

TABLE 8

PROBLEM #13

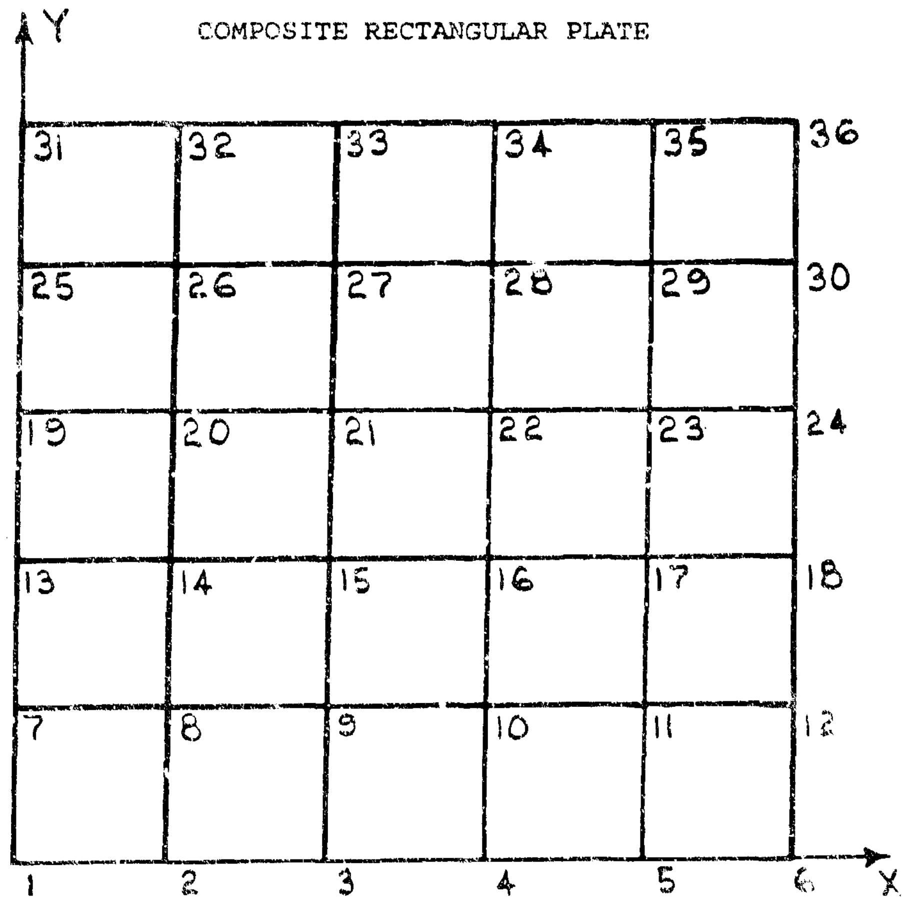


FIGURE 13

A composite rectangular plate modeled with the symmetric lay-up [45, -45, 90, 0, 0, 90, -45, 45] is shown in Fig. 13. The model contains 36 nodes and 25 elements. The length of the plate is 20, the width is 15, and the thickness of each layer is .0236. The material properties are given as $E_1=18.5\times10^6$, $E_2=1.6\times10^6$, $\nu_{12}=0.25$, $G_{12}=.65\times10^6$ and $G_{12}=G_{22}=4.0\times10^5$. Four variations of the plate are considered.

CASE 1: The plate is modeled as a membrane subjected to a compression load in the -X direction at the X=15.0 edge.

CASE 2: The plate is modeled with bending properties and subjected to a uniform pressure load of 2 in the -Z direction.

CASE 3: The plate is modeled in membrane and bending and is subject to the loads defined in Case 1 and Case 2.

CASES 1 through 3 are defined for a static analysis, RF #1.

CASE 4: Normal modes analysis using RF #3. The first ten natural frequencies are found.

PROBLEM #14

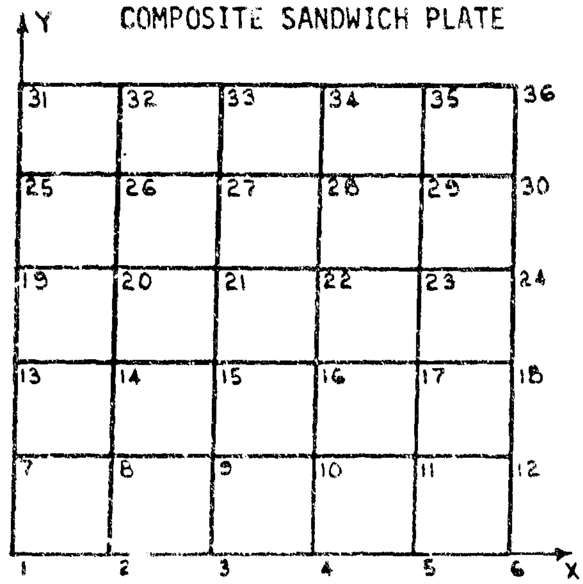
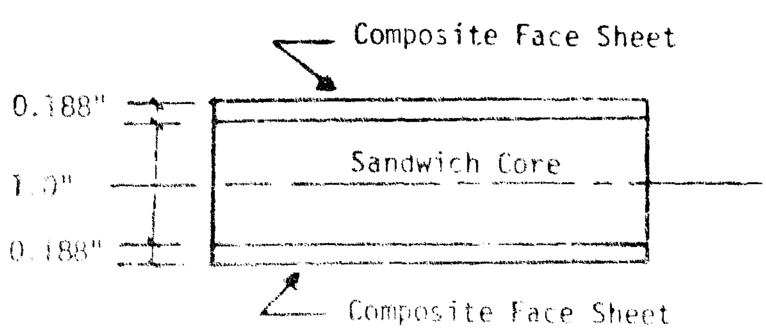


FIGURE 14

A sandwich plate with an isotropic core and composite skins modeled with the symmetric lay-up [45, -45, 90, 0, 0, 90, -45, 45] is shown in Fig 14. The model contains 35 nodes and 25 elements. The length of the plate is 20, the width is 15, the thickness of each layer is .0236, and the thickness of the core is 1. The material properties of the composite skin are given as $E_1=18.5\times10^6$, $E_2=1.6\times10^6$, $\nu=0.25$ and $G_{12}=.65\times10^6$, $G_{1Z}=G_{2Z}=4.0\times10^5$. The material properties of the core are given as $G=3.0\times10^4$. The plate is subjected to a uniform pressure load of 2.

ELEMENT DEFINITION

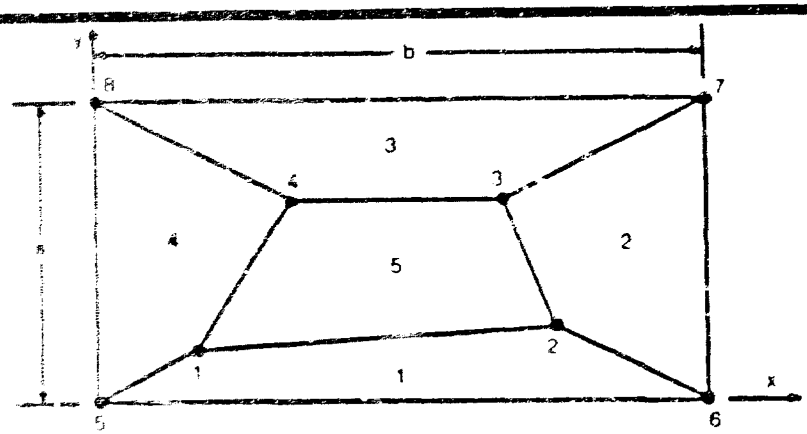


B.2 RESULTS AND COMPARISONS

MCS 5-8-129

PATCH TEST

PROBLEM #1



$a = .12 \quad b = .24 \quad t = .001$

$E = 1.0E+6$

$\nu = 0.25$

MEMBRANE PLATE

B.C. $\begin{cases} u = 10^{-3}(x + y/2) \\ v = 10^{-3}(y + x/2) \end{cases}$

MAXIMUM ERROR IN σ_x

LOADING	QUAD2	QUAD4 COSMIC	QUAD4 MSC	THEORY σ_x
CONSTRANT STRESS	0.0	0.0	0.0	1333.
CONSTANT CURVATURE	33.1%	0.0	0.0	±.667

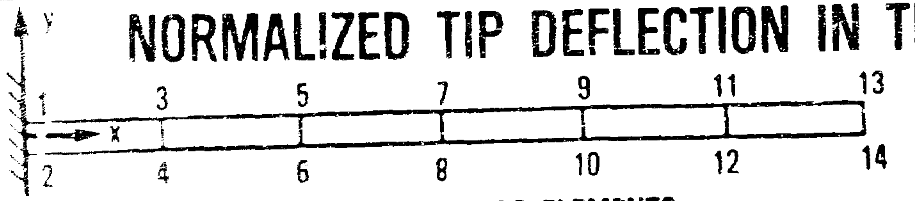
BENDING PLATE

B.C. $\begin{cases} W = 10^{-3}(x^2 + xy + y^2)/2 \\ \theta x = 10^{-3}(y + x/2) \\ \theta y = 10^{-3}(-x - y/2) \end{cases}$

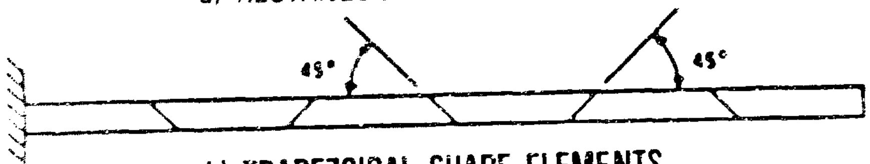
STRAIGHT CANTILEVER BEAM

PROBLEM #2

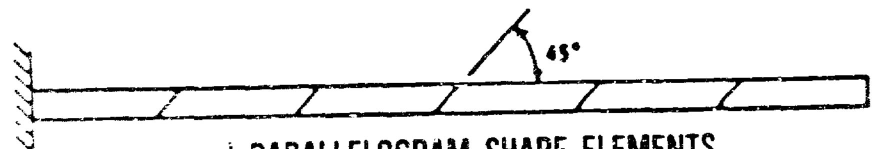
NORMALIZED TIP DEFLECTION IN THE DIRECTION OF THE LOAD



a) RECTANGULAR SHAPE ELEMENTS



b) TRAPEZOIDAL SHAPE ELEMENTS



c) PARALLELOGRAM SHAPE ELEMENTS

L = 6.0 W = 0.2 D = 0.1
E = 1.0E7 ν = .30
UNIT FORCES AT THE TIP

RECTANGULAR

	QUAD2	QUAD4	
		COSMIC	MSC
EXTENSION	.992	.995	.995
IN PLANE SHEAR	.032	.904	.904
OUT-OF-PLANE SHEAR	.971	.985	.986
TWIST	.566	.959	.902

PARALLELOGRAM

	QUAD2	QUAD4	
		COSMIC	MSC
EXTENSION	.992	.991	.996
IN-PLANE SHEAR	.013	.078	.078
OUT-OF-PLANE SHEAR	.960	.987	.976
TWIST	.598	.881	.904

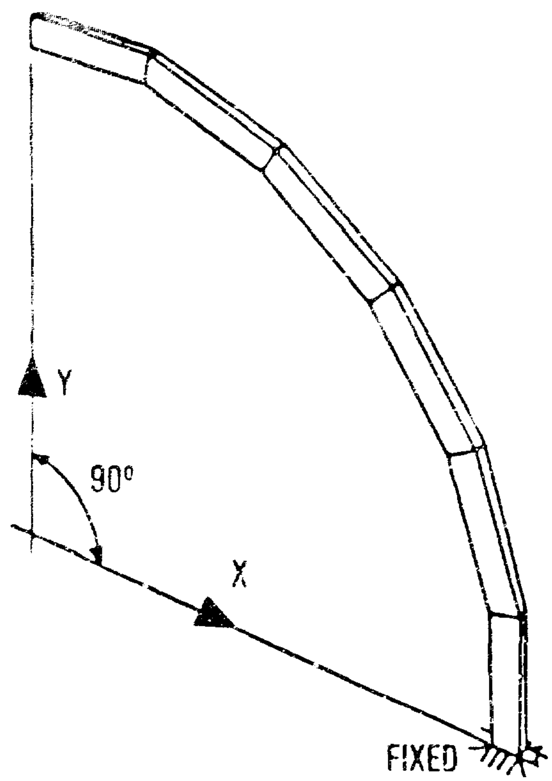
TRAPEZOIDAL

	QUAD2	QUAD4	
		COSMIC	MSC
EXTENSION	.992	.996	.996
IN PLANE SHEAR	.017	.070	.071
OUT-OF-PLANE SHEAR	.965	.981	.968
TWIST	.631	.916	.913

CURVED BEAM

PROBLEM #3

NORMALIZED TIP DISPLACEMENT IN THE DIRECTION OF THE LOAD



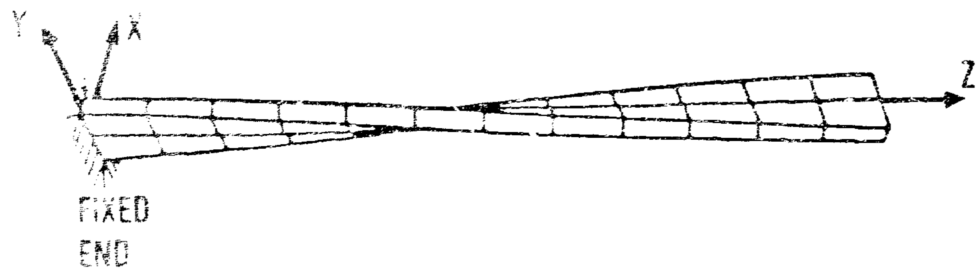
INNER RADIUS = 4.12
OUTER RADIUS = 4.32
THICKNESS = .1
E = 1.0E7
ν = .25

	QUAD2	QUAD4 COSMIC	QUAD4 MSC
IN-PLANE (VERTICAL)	.025	.833	.833
OUT-OF-PLANE	.596	.950	.923

TWISTED BEAM

PROBLEM #4

NORMALIZED TIP DEFLECTION IN THE DIRECTION OF THE LOAD



L = 12.0   W = 1.1   D = .32
TWIST = 90° (ROOT TO TIP)
E = 29.0E6
ν = 0.22

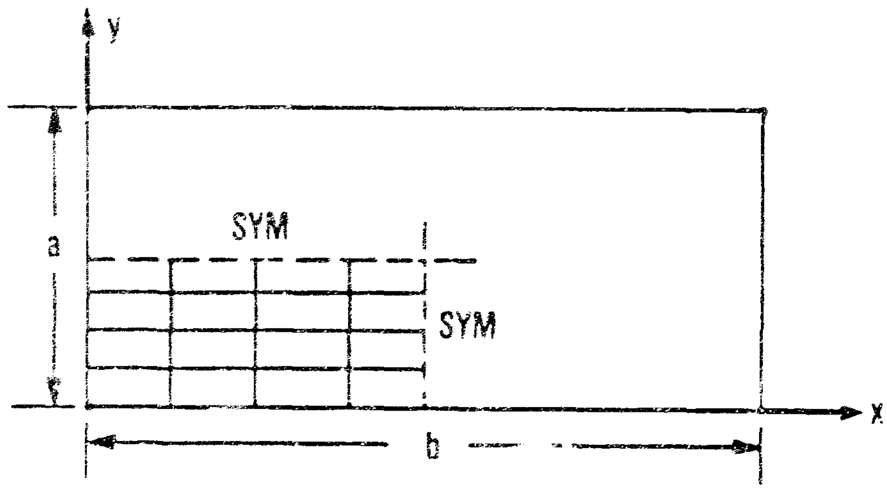
UNIT FORCES AT THE TIP

	QUAD2	QUAD4 COSMIC	QUAD4 MSC
IN-PLANE	98.46	.995	.993
OUT-OF-PLANE	226.4	.985	.985

RECTANGULAR PLATE CLAMPED SUPPORTS

PROBLEM #5

NORMALIZED LATERAL DEFLECTI[illegible]



a = 2.0 b = 2.0 OR 10.0
THICKNESS = 0.001
E = 1.7472E7
ν = 0.3
CENTRAL LOAD = 4.0E4

ASPECT RATIO = 1.0

MESH	QUAD2	QUAD4	
		COSMIC	MSC
2x2	.983	.997	.938
4x4	1.012	1.034	1.014
6x6	1.010	1.026	1.016
8x8	1.009	1.019	1.014

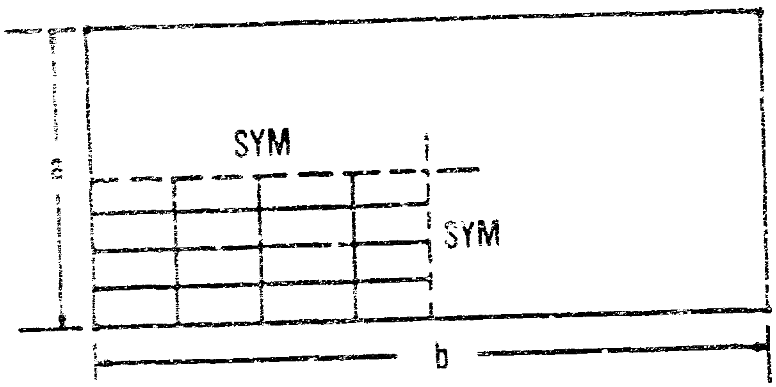
ASPECT RATIO = 5.0

MESH	QUAD2	QUAD4	
		COSMIC	MSC
2x2	.333	.773	.519
4x4	.513	1.028	.863
6x6	.639	1.058	.940
8x8	.725	1.057	.972

RECTANGULAR PLATE SIMPLE SUPPORTS

PROBLEM #5

NORMALIZED LATERAL DEFLECTION AT THE CENTER



a = 2.0 b = 2.0 OR 10.0
THICKNESS = 0.001
E = 1.7472E7
ν = 0.3
UNIFORM PRESSURE q = 1.0E-4

ASPECT RATIO = 1.0

MESH	QUAD2	QUAD4 COSMIC	QUAD4 MSC
2x2	.975	1.030	.981
4x4	.998	1.013	1.004
6x6	1.001	1.009	1.003
8x8	1.002	1.006	1.002

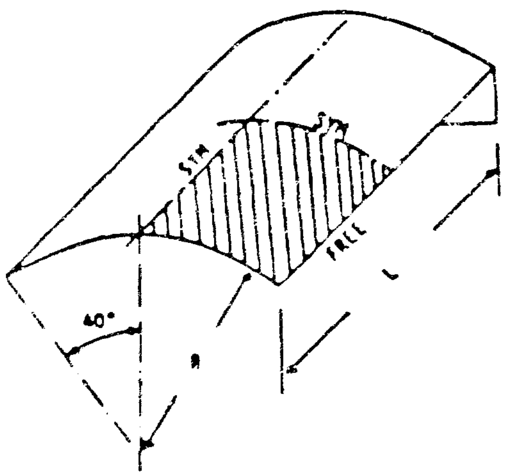
ASPECT RATIO = 5.0

MESH	QUAD2	QUAD4 COSMIC	QUAD4 MSC
2x2	1.005	.913	.999
4x4	1.014	.991	.995
6x6	1.007	.996	1.000
8x8	1.005	.998	1.001

SCORDELIS - LO - ROOF

PROBLEM #6

NORMALIZED VERTICAL DEFLECTION AT THE MIDPOINT OF THE FREE EDGE



RADIUS = 25.0 FT
LENGTH = 50.0 FT
THICKNESS = 0.25 FT
E = 4.32E8 LBS / FT²
ν = 0.0

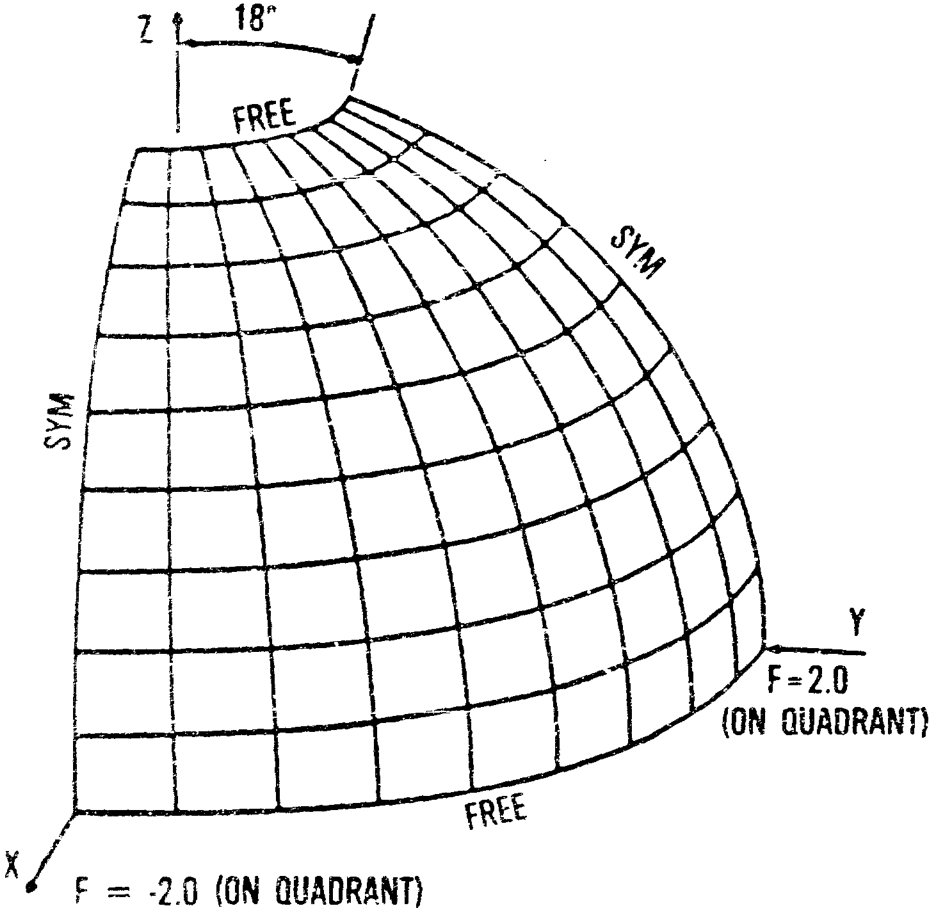
LOADED BY ITS OWN WEIGHT - 90 LBS / FT²
$U_X = U_Z = 0$ ON CURVED EDGES

MESH	QUAD2	QUAD4	
		COSMIC	MSC
2x2	.900	1.419	1.376
4x4	.691	1.047	1.050
6x6	.791	.999	1.018
8x8	.859	.978	1.008
10x10	.896	.966	1.004

SPHERICAL SHELL

PROBLEM #7

NORMALIZED RADIAL DEFLECTION AT THE CENTER



RADIUS = 10.0
THICKNESS = .04
E = 6.825E7
ν = 0.3

MESH	QUAD2	QUAD4 COSMIC	QUAD4 MSC
2X2	.928	1.051	.972
4x4	.990	1.054	1.024
6x6	.990	1.030	1.013
8x8	.986	1.015	1.005
10x10	.984	1.007	1.001
12x12	.982	1.003	.998

SUMMARY OF TEST RESULTS

TEST DESCRIPTION	ELEMENT IN-PLANE	LOADING OUT-OF-PLANE	ELEMENT SHAPE	COSMIC QUAD 2	COSMIC QUAD 4	MSC¹ QUAD 4
1. PATCH TEST	X		IRREGULAR	A	A	A
2. PATCH TEST		X	IRREGULAR	D	A	A
3. STRAIGHT BEAM, EXTENSION	X		ALL	A	A	A
4. STRAIGHT BEAM, BENDING	X		REGULAR	F	B	B
5. STRAIGHT BEAM ,BENDING	X		IRREGULAR	F	F	F
6. STRAIGHT BEAM, BENDING		X	REGULAR	B	A	A
7. STRAIGHT BEAM, BENDING		X	IRREGULAR	B	A	B
8. STRAIGHT BEAM, TWIST			ALL	D	B	B
9. CURVED BEAM	X		REGULAR	F	C	C
10. CURVED BEAM		X	REGULAR	D	B	B
11. TWISTED BEAM	X	X	REGULAR	F	A	A
12. RECTANGULAR PLAT (5x5)		X	REGULAR	A	A	A
13. SCORDELIS-LO ROOF (5x5)	X	X	REGULAR	D	B	B
14. SPHERICAL SHELL (9x9)	X	X	REGULAR	A	A	A

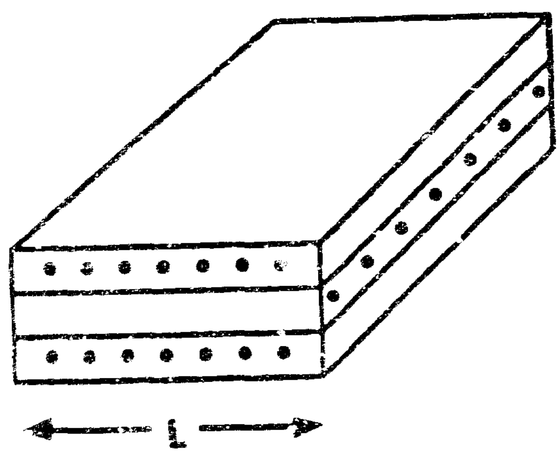
¹ MSC/NASTRAN IS A SERVICE AND TRADEMARK OF MACNEAL-SCHWENDER CORP

GRADE SCORES ARE DEFINED BY:

A. ERROR LESS THAN 2%
B ERROR BETWEEN 2% AND 10%
C. ERROR BETWEEN 10% AND 20%
D. ERROR BETWEEN 20% AND 50%
F. ERROR EXCEEDS 50%

LAMINATED COMPOSITE PLATE – PURE TWIST LOADING

PROBLEM #8



REGULAR SYMMETRIC
CROSS-PLY LAMINATE

A SQUARE PLATE OF A 4X4 MESH WITH THREE CORNERS PINNED AND A TRANSVERSE POINT LOAD AT THE FREE CORNER TO SIMULATE A PURE TWIST LOADING

$T_1 = T_2 = T_3 = .02222$
$E_1 = 2.0E7$
$E_2 = 5.0E5$
$NU_{12} = 0.25$
$G_{12} = 2.5E5$

$L = 5.0$
$\theta_1 = \theta_3 = 0.0$
$\theta_2 = 90.0$

COMPARISON OF T3 DEFLECTION AT GRID 1

COSMIC/NASTRAN	MSC/NASTRAN	THEORETICAL
-3.758E-2	-3.769E-2	-3.750E-3
(1.002)*	(1.005)	

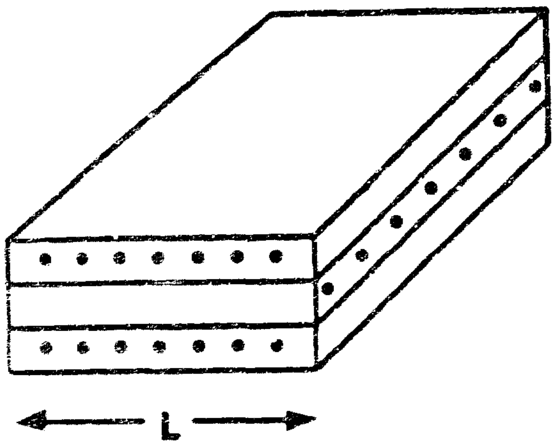
COMPARISION OF TAU FOR ELEMENT 1,
ALL LAYERS

	COSMIC/NASTRAN	MSC/NASTRAN	THEORETICAL
PLY 1	-5.0E1	-5.0E1	-5.0E1
PLY 2	0.0E1	0.0	0.0
PLY 3	5.0E1	5.0E1	5.0E1

*NORMALIZED VALUE

LAMINATED COMPOSITE PLATE

PROBLEM #9



REGULAR SYMMETRIC
CROSS-PLY LAMINATE

SIMPLY SUPPORTED
UNIFORM PRESSURE LOAD

$T_1 = T_2 = T_3 = .000666$
$E_1 = 2.0E7$
$E_2 = 5.0E5$
$NU_{12} = 0.25$
$G_{12} = 2.5E5$

$L = 1.0$
$P = 1.0\ E\text{-}4$
$\theta_1 = \theta_3 = 0.0$
$\theta_2 = 90.0$

COMPARISON OF T3 DEFLECTION AT GRID 25

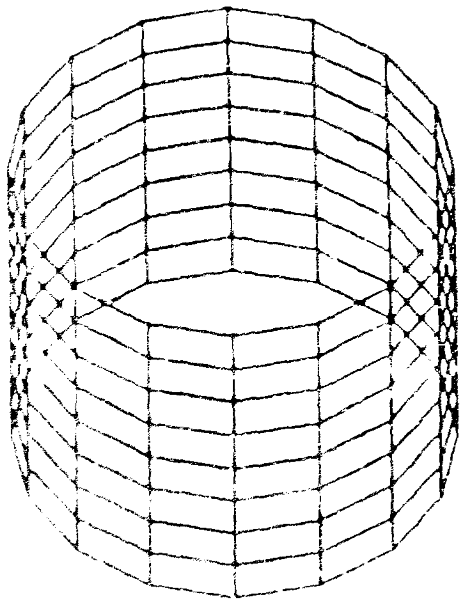
COSMIC/NASTRAN	MSC/NASTRAN	THEORETICAL
-1.852E-3	-1.739E-3	-1.836E-3
(1.009)*	(.947)	

STRESS RESULTS		
LAYER 1&3	COSMIC 04	THEORY
σ_1	53.6	58.6
σ_2	1.4	1.8
τ_{12}	-.04	-.06

*NORMALIZED VALUE

LAMINATED COMPOSITE OPEN TUBE OF RADIUS 50.0

PROBLEM #10



SYMMETRIC
8 LAYERS

[45,-45,0,90,90,0,-45,45]

CONSTANT PRESSURE

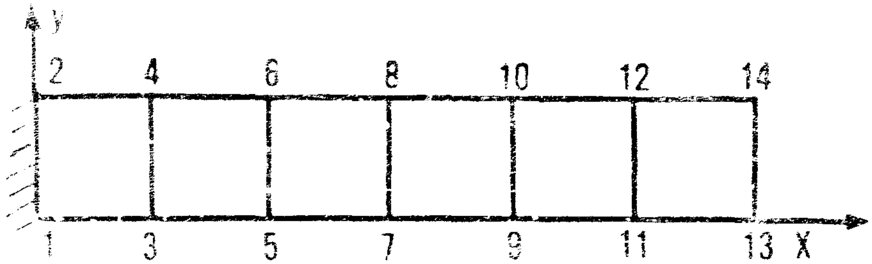
$T_i = .24 \quad i = 1,...,8$
$E_1 = 73.8E3 \quad L = 80.0$
$E_2 = 3.75E3 \quad P = 10.5$
$NU_{12} = 0.4$
$G_{12} = 1.74E3$

COMPARISON OF σ_1 LAYER STRESS FOR ELEMENT ID 8

LAYER	COSMIC/NASTRAN	MSC/NASTRAN
1	2.425E2	2.519E2
2	2.543E2	2.494E2
3	-2.268E2	-2.257E2
4	7.252E2	7.268E2
5	7.252E2	7.269E2
6	-2.238E2	-2.255E2
7	2.560E2	2.535E2
8	2.472E2	2.478E2

STRAIGHT BEAM TEST

PROBLEM #11



CANTILEVERED BEAM MODEL UNDER A) EXTENSIONAL AND B) BENDING LOADINGS SIMULATION OF EQUIVALENT ISOTROPIC PROPERTIES. LAMINATE CONFIGURATION

[0/0/0/0]

$T_i = .25$ $\quad i = 1, \ldots, 4$

$E_i = 10.0E6$ $\quad l = 6.0$

$\nu = .3$

COMPARISON OF T1 DEFLECTION AT GRIDS 13 AND 14

(EXTENSIONAL)

	COSMIC/NASTRAN	MSC/NASTRAN	THEORETICAL
GRID 13	2.986E-5	2.986E-5	3.0E-5
GRID 14	2.986E-5	2.986E-5	3.0E-5

(BENDING)

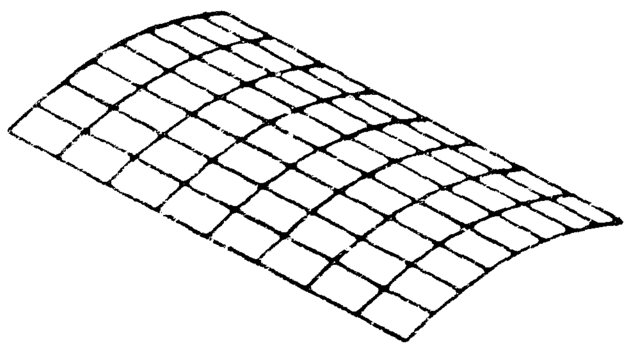
	COSMIC/NASTRAN	MSC/NASTRAN	THEORETICAL
GRID 13	4.224E-1	4.253E-1	4.320E-1
GRID 14	4.224E-1	4.253E-1	4.320E-1

COMPARISON OF DIRECT LAYER BENDING STRESS
ELEMENT 6 (LARGEST BENDING MOMENT)

LAYER	COSMIC/NASTRAN	MSC/NASTRAN
1	1.238E4	1.238E4
2	4.125E3	4.126E3
3	-4.125E3	-4.126E3
4	-1.238E4	-1.238E4

LAMINATED COMPOSITE SHELL ROOF MODEL

PROBLEM #12



$T_i = .03125 \quad i = 1, \ldots, 8$

$E_1 = 2.0E8 \quad L = 25.0 \quad RADIUS = 25.0$

$E_2 = 0.5E7 \quad P = 90.0$

$NU_{12} = 0.25 \quad G_{12} = 2.5E6$

$G_{12} = 2.5E6 \quad G_{22} = 2.5E6$

SYMMETRIC ANGLE PLY

8 LAYERS

[45, -45, 15, -15, -15, 15, -45, 45]

UNIFORM PRESSURE

COMPARISON OF T1 DEFLECTION AT SELECTED GRIDS		
GRID	COSMIC/NASTRAN	MSC/NASTRAN
34	-1.0735	-1.0662
35	-1.3545	-1.3441
36	-1.6213	-1.6074
43	-1.3363	-1.3267
44	-1.6876	-1.6739
45	-2.0267	-2.0079

APPENDIX C: CASE CONTROL AND BULK DATA CARDS PERTAINING TO THE QUAD4 ELEMENT

Case Control Data Card ELSTRESS - Element Stress Output Request

Description: Requests form and type of element stress output.

Format and Example(s):

```
ELSTRESS  [( SØRT1 , PRINT    , EXTREME , REAL  )] = { ALL  }
             SØRT2   PUNCH      LAYER     IMAG         n
                     NØPRINT              PHASE        NØNE
```

ELSTRESS = 5

ELSTRESS = ALL

ELSTRESS(SØRT1, PRINT, PUNCH, PHASE) = 15

Option	Meaning
SØRT1	Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each element type. SØRT2 is available only in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
EXTREME or LAYER	Requests stresses to be calculated at the extreme (top and bottom) fibers of a plate element or, for composites, the stresses for each layer. (See Remark 8)
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase (0.0° ≤ phase < 360.0°) on Complex Eigenvalue or Frequency Response problems.
ALL	Stresses for all elements will be output.
n	Set identification of a previously appearing SET card (Integer > 0). Only stresses for elements whose identification numbers appear on this SET card will be output.
NØNE	Stresses for no elements will be output.

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. ELSTRESS is an alternate form and is entirely equivalent to STRESS.
5. ELSTRESS = NØNE allows overriding an overall request.

(Continued)

ELSTRESS (Continued)

6. If element stresses in material coordinate system are desired (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements and only in Rigid Format 1), the parameter STRESS (see the description of the PARAM bulk data card in Section 2.4.2) should be set to be a positive integer. If, in addition to element stresses in material coordinate system, stresses at the connected grid points are also desired, the parameter STRESS should be set to 0.

7. When LAYER is selected, individual layer stresses and/or failure indices will be output.

8. The option EXTREME and LAYER is only applicable for the QUAD4 element.

Case Control Data Card STRESS - Element Stress Output Request

Description: Requests form and type of element stress output.

Format and Example(s):

```
STRESS  [( SØRT1     PRINT      EXTREME     REAL  )]   { ALL  }
        [( SØRT2  ,  PUNCH   ,  LAYER    ,  IMAG  )] = {  n   }
        [(           NØPRINT                PHASE )]   { NØNE }
```

STRESS = 5

STRESS = ALL

STRESS(SØRT1, PRINT, PUNCH, PHASE) = 15

Option	Meaning
SØRT1	Output will be presented as a tabular listing of elements for each load, frequency, eigenvalue, or time, depending on the rigid format. SØRT1 is not available in Transient problems (where the default is SØRT2).
SØRT2	Output will be presented as a tabular listing of load, frequency, or time for each element type. SØRT2 is available *only* in Static Analysis, Transient and Frequency Response problems.
PRINT	The printer will be the output media.
PUNCH	The card punch will be the output media.
EXTREME or LAYER	Requests stresses to be calculated at the extreme (top and bottom) fibers of a plate element or, for composites, the stresses for each layer. (See Remark 8)
REAL or IMAG	Requests real and imaginary output on Complex Eigenvalue or Frequency Response problems.
PHASE	Requests magnitude and phase (0.0° ≤ phase < 360.0°) on Complex Eigenvalue or Frequency Response problems.
ALL	Stresses for all elements will be output.
n	Set identification of a previously appearing SET card (Integer > 0). Only stresses for elements whose identification numbers appear on this SET card will be output.
NØNE	Stresses for no elements will be output.

Remarks:

1. Both PRINT and PUNCH may be requested.
2. An output request for ALL in Transient and Frequency response problems generally produces large amounts of printout. An alternative to this would be to define a SET of interest.
3. In Static Analysis or Frequency Response problems, any request for SØRT2 output causes all output to be SØRT2.
4. STRESS is an alternate form and is entirely equivalent to ELSTRESS.
5. STRESS = NØNE allows overriding an overall request.

(Continued)

STRESS (Continued)

6. If element stresses in material coordinate system are desired (only for TRIA1, TRIA2, QUAD1 and QUAD2 elements and only in Rigid Format 1), the parameter STRESS (see the description of the PARAM bulk data card in Section 2.4.2) should be set to be a positive integer. If, in addition to element stresses in material coordinate system, stresses at the connected grid points are also desired, the parameter STRESS should be set to 0.

7. When LAYER is selected, individual layer stresses and/or failure indices will be output.

8. The option EXTREME and LAYER is only applicable for the QUAD4 element.

Input Data Card COQUAD4 Quadrilateral Element Connection

Description: Defines a quadrilaterial plate element (QUAD4) of the structural model. This is an isoparametric membrane-bending element, with variable element thickness, layered composite material and thermal analysis capabilities.

Format and Example:

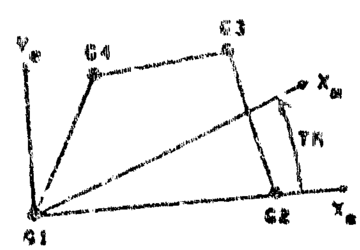
1	2	3	4	5	6	7	8	9	10
CQUAD4	EID	PID	G1	G2	G3	G4	TM	ZO	abc
CQUAD4	101	17	1001	1005	1010	1024	45.0	0.01	ABC

+bc	X	X	T1	T2	T3	T4	X	X	X
+BC			0.03	0.125	0.05	0.04			

Field	Contents
EID	Element identification number (Integer > 0)
PID	Identification number of a PSHELL entry (Default is EID) (Integer > 0) For composites, see Remark 5.
Gi	Grid point identification numbers of connection points (Integer > 0)
ZO	Offset of the element reference plane from the plane of grid points (Real or blank, see Remark 3 for default)
TM	Material property orientation specification (Real or blank; or 0 ≤ Integer < 1,000,000). If Real or blank, specifies the material property orientation angle in degrees. If Integer, the orientation of the material x-axis is along the projection onto the plane of the element of the x-axis of the coordinate system specified by the integer value.
Ti	Membrane thickness of element at grid points Gi (Real or blank, see Remark 4 for default).

Remarks:

1. The QUAD4 geometry, coordinate systems and numbering are shown in the figure below:



2. Element identification numbers must be unique with respect to all other element identification numbers.

(Continued)

2.4-87a (8/10/87)

3. The material coordinate system (TM) and the offset (ZO) may also be provided on the PSHELL entry. The PSHELL data will be used if the corresponding field on the CQUAD4 entry is blank.

4. The Ti are optional, if not supplied they will be set to the value of T specified on the PSHELL entry. In such cases, the continuation entry is not required.

5. For composites, a PCOMP, PCOMP1, PCOMP2 card can be used instead of a PSHELL card.

Input Data Card MAT2 Material Property Definition

Description: Defines the material properties for linear, temperature-independent, anisotropic materials.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT2	MID	G11	G12	G13	G22	G23	G33	RHO	+abc
MAT2	13	6.2+3			6.2+3		5.1+3	0.056	ABC
+abc	A1	A2	A12	TO	GE	ST	SC	SS	+def
+BC	0.15			-500.0	0.002	20.+5			DEF
+def	MCSID								
+EF	1008								

Field	Contents
MID	Material identification number (Integer > 0)
Gij	The material property matrix (Real)
RHØ	Mass density (Real)
Ai	Thermal expansion coefficient vector (Real)
TO	Thermal expansion reference temperature (Real)
GE	Structural element damping coefficient (Real)
ST, SC, SS	Stress limits for tension, compression and shear (Real) (Used only to compute margins of safety in certain elements; they have no effect on the computational procedures)
MCSID	Material coordinate system identification number (Integer $\geq$ 0 or blank)

Remarks:

1. The material identification numbers must be unique for all MAT1, MAT2 and MAT3 cards.
2. MAT2 materials may be made temperature dependent by use of the MATT2 card.
3. The mass density, RHØ, will be used to automatically compute mass for all structural elements except the two-dimensional bending only elements TRBSC, TRPLT and QDPLT.
4. The convention for the G_{ij} in fields 3 through 8 is represented by the matrix relationship.

$$\begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} = \begin{bmatrix} G_{11} & G_{12} & G_{13} \\ G_{12} & G_{22} & G_{23} \\ G_{13} & G_{23} & G_{33} \end{bmatrix} \cdot \begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \gamma_{12} \end{Bmatrix}$$

5. MCSID (> 0) is required if stresses or strains/curvatures are to be computed in a material coordinate system. This is applicable only for TRIA1, TRIA2, QUAD1, and QUAD2 elements.

Input Data Card MAT8 Orthotropic Plate Material Property Definition

Description: Defines the material property for an orthotropic material for plate elements.

Format and Example:

1	2	3	4	5	6	7	8	9	10
MAT8	MID	E1	E2	NU12	G12	G1Z	G2Z	RHO	abc
MAT8	299	32.+6	4.2+5	0.33	2.9+6			0.042	ABC

+bc	A1	A2	TREF	XT	XC	YT	YC	S	def
+BC	14.-6	2.3-6	175.						DEF

+ef	GE	F12							
+EF	2.5-4								

Field	Contents
MID	Material identification number (Integer > 0)
E1,E2	Modulus of elasticity in the material x and y directions (Real ≠ 0.0)
NU12	Poisson's Ratio (Real) (See Remark 5)
G12	Linear in-plane shear modulus (Real > 0.0)
G1Z	Transverse shear modulus for shear in X-Z plane (Real)
G2Z	Transverse shear modulus for shear in Y-Z plane (Real)
RHO	Mass density (Real)
A1,A2	Thermal expansion coefficients in the material x and y directions (T, Real > 0.0)
TREF	Thermal expansion reference temperature (XC, Real)
XT,XC	Allowable stresses/strains in tension and compression, respectively, in the material x direction. Required if failure index calculation is desired. (XT, Real > 0.0) (XC, Real) (Default value for XC is XT) (See Remark 3)
YT,YC	Allowable stresses/strains in tension and compression, respectively, in the material y direction. Required if failure index calculation is desired. (YT, Real > 0.0) (YC, Real) (Default value for YC is YT) (See Remark 3)
S	Allowable stress/strain for in-plane shear (Real > 0.0) (See Remark 3)
GE	Structural damping coefficient (Real)
F12	Tsai-Wu interaction term (Real) (See Remark 4)

(Continued)

Remarks: 1. Material coordinate systems are defined by the plate element connection entries on the CQUAD4 card.

2. The stress-strain relationship defined by this data is:

$$\begin{Bmatrix} \epsilon_1 \\ \epsilon_2 \\ \gamma_{12} \end{Bmatrix} = \begin{bmatrix} 1/E1 & -NU12/E1 & 0 \\ -NU12/E1 & 1/E2 & 0 \\ 0 & 0 & 1/G12 \end{bmatrix} \begin{Bmatrix} \sigma_1 \\ \sigma_2 \\ \tau_{12} \end{Bmatrix} + (T-TREF) \begin{Bmatrix} A1 \\ A2 \\ 0 \end{Bmatrix}$$

$$\begin{Bmatrix} \tau_{xz} \\ \tau_{yz} \end{Bmatrix} = \begin{bmatrix} G1Z & 0 \\ 0 & G2Z \end{bmatrix} \begin{Bmatrix} \gamma_{xz} \\ \gamma_{yz} \end{Bmatrix}$$

3. Fields XT, XC, YT, YC and S are used only for composite materials when failure calculations are requested with PCOMP, PCOMP1 or PCOMP2 Bulk Data entries. Allowables represent stresses except when the maximum strain failure theory is used.

4. The F12 field is used only for composite materials when the Tsai-Wu failure theory is used and failure calculations are requested.

5. NU12 is Poisson's Ratio (ϵ_1/ϵ_2 for uniaxial loading in 1-direction). Note that NU21 $=\epsilon_2/\epsilon_1$ uniaxial loading in 2-direction, is related to NU12, E1 and E2 by the relationship, (NU12) (E2) = (NU21) (E1).

Input Data Card PCOMP Layered Composite Element Property

Description: Defines the properties of a n-ply laminated composite material.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PCOMP	PID	ZO	NSM	SBOND	FT			LOPT	abc
PCOMP	100	-0.5	1.5	5.+3	HOFF			SYMMEM	ABC
+bc	MID1	T1	TH1	SOUT1	MID2	T2	TH2	SOUT2	def
+BC	150	0.05	90.	YES			-45.		DEF
+ef	MID3	T3	TH3	SOUT3	ETC. . .				
+EF			45.0		. . . . .				

Field	Contents
PID	Property identification number (1,000,000 > Integer > 0)
ZO	Offset of the element reference plane from the plane of grid points (Real or blank, see Remark 2)
NSM	Non-structural mass per unit area. (Real)
SBOND	Allowable shear stress of the bonding material. (Real > 0.0 or blank) Required if failure theory is used.
FT	Failure theory, one of the strings "HILL", "HOFF", "TSAI", "STRESS", or "STRAIN". See Remark 4. (BCD or blank)
LOPT	Lamination generation option, one of the strings, "ALL", "SYM", "MEM", or "SYMMEM". See Remark 5. (BCD or blank) Default is all.
MIDi	Material identification number of the i^{th} layer. (Integer > 0 or blank)
Ti	Thickness of the i^{th} layer (Real, > 0.0 or blank)
THi	Angle between the longitudinal direction of the fibers of the i^{th} layer and the material X-axis. (Real or blank)
SOUTi	Stress output request for i^{th} later, one of the strings "YES" or "NO". (Default is "NO")

Remarks:
1. The plies are numbered from 1 to n beginning with the bottom layer.
2. The offset (ZO) is used only when the corresponding field on the CQUAD4 Bulk Data entry referencing this property are blank.

(Continued)

<u>PCOMP</u> (Continued)

3. SBOND is required if bonding material failure index calculations are desired.

4. The failure theory is used to determine the element failure on a ply-by-ply basis. The available theories are:

HILL	- Hill Theory
HOFF	- Hoffman Theory
TSAI	- Tsai-Wu Theory
STRESS	- For Maximum Stress Theory
STRAIN	- For Maximum Strain Theory

5. To minimize input requirements several lamination options (LOPT) are available. All indicates that every ply is specified, SYM indicates that ply layup is symmetric about the center ply and that the plies on one side of the center line are specified. SYMMEM indicates a symmetric layup of membrane only plies.

6. The material properties, MIDi, may reference only MAT1, MAT2 and MAT8 Bulk Data entries.

7. If any of the MIDi, Ti or THi are blank, then the last non-blank values specified for each will be used to define the values for the ply.

Input Data Card PCOMP1 Layered Composite Element Property

Description: Defines the properties of a n-ply laminated composite material where all plies are composed of the same material and are of equal thickness.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PCOMP1	PID	ZO	NSM	SBOND	FT	MID	TPLY	LOPT	abc
PCOMP1	100	-0.5	1.7	5.+3	STRAIN	200	0.25	SYM	ABC

+bc	TH1	TH2	TH3	TH4	TH5	ETC. . .		
+BC	-45.0	45.0	90.0	90.0	45.0	. . . . .		

Field	Contents
PID	Property identification number (1,000,000 > Integer > 0)
ZO	Offset of the element reference plane from the plane of grid points (Real or blank, see Remark 2)
NSM	Non-structural mass per unit area. (Real)
SBOND	Allowable shear stress of the bonding material. (Real > 0.0)
FT	Failure theory, one of the strings "HILL", "HOFF", "TSAI", "STRESS", or "STRAIN". See Remark 4.
MID	Material identification number for all layers. (Integer > 0)
LOPT	Lamination generation option, one of the strings, "ALL", "SYM", "MEM", or "SYMMEM". See Remark 5.
TPLY	Thickness of all layers (Real, > 0.0 or blank)
THi	Angle between the longitudinal direction of the fibers of the i^{th} layer and the material X-axis. (Real or blank)

Remarks:

1. The plies are numbered from 1 to n beginning with the bottom layer.
2. The offset (ZO) is used only when the corresponding field on the CQUAD4 Bulk Data entry referencing this property is blank.
3. SBOND is required if bonding material failure index calculations are desired.
4. The failure theory is used to determine the element failure on a ply-by-ply basis. The available theories are:

   HILL - Hill Theory
   HOFF - Hoffman Theory
   TSAI - Tsai-Wu Theory
   STRESS - For Maximum Stress Theory
   STRAIN - For Maximum Strain Theory

(Continued)

<u>PCOMP1</u> (Continued)

5. To minimize input requirements several lamination options (LOPT) are available. All indicates that every ply is specified, SYM indicates that ply layup is symmetric about the center ply and that the plies on one side of the center line are specified. SYMMEM indicates a symmetric layup of membrane only plies.

6. The material property, MID, may reference only MAT1, MAT2 and MAT8 Bulk Data entries.

Input Data Card PCOMP2 Layered Composite Element Property

Description: Defines the properties of a n-ply laminated composite material where all plies are composed of the same material.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PCOMP2	PID	ZO	NSM	SBOND	FT	MID	X	LOPT	abc
PCOMP2	100	-0.5	1.7	5.+3	TSAI	200		SYM	ABC

+bc	T1	TH1	T2	TH2	T3	TH3	ETC. . .	
+BC	0.25	-45.0	0.5	90.0	0.25	45.0	. . . . .	

Field	Contents
PID	Property identification number (1,000,000 > Integer > 0)
ZO	Offset of the element reference plane from the plane of grid points (Real or blank, see Remark 2)
NSM	Non-structural mass per unit area. (Real)
SBOND	Allowable shear stress of the bonding material. (Real > 0.0)
FT	Failure theory, one of the strings "HILL", "HOFF", "TSAI", "STRESS", or "STRAIN". See Remark 4.
MID	Material identification number for all layers. (Integer > 0 or blank)
LOPT	Lamination generation option, one of the strings, "ALL", "SYM", "MEM", or "SYMMEM". See Remark 5.
Ti	Thickness of the i^{th} layer (Real, > 0.0 or blank)
THi	Angle between the longitudinal direction of the fibers of the i^{th} layer and the material X-axis. (Real or blank)

Remarks:

1. The plies are numbered from 1 to n beginning with the bottom layer.
2. The offset (ZO) is used only when the corresponding field on the CQUAD4 Bulk Data entry referencing this property is blank.
3. SBOND is required if bonding material failure index calculations are desired.
4. The failure theory is used to determine the element failure on a ply-by-ply basis. The available theories are:

   HILL - Hill Theory
   HOFF - Hoffman Theory
   TSAI - Tsai-Wu Theory
   STRESS - For Maximum Stress Theory
   STRAIN - For Maximum Strain Theory

(Continued)

PCOMP2 (Continued)

5. To minimize input requirements several lamination options (LOPT) are available. All indicates that every ply is specified, SYM indicates that ply layup is symmetric about the center ply and that the plies on one side of the center line are specified. SYMMEM indicates a symmetric layup of membrane only plies.

6. The material property, MID, may reference only MAT1, MAT2 and MAT8 Bulk Data entries.

7. If any of the Ti or THi are blank, then the last non-blank values specified for each will be used to define the values for the ply.

Input Data Card PLOAD4 Pressure Loads on Face of Structural Elements

Description: Defines a load on a face of a QUAD4 element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PLOAD4	SID	EID	P1	P2	P3	P4			abc
PLOAD4	101	2043	15.	18.	23.6				ABC

+bc	CID	N1	N2	N3					
+BC	52	1.0	0.	0.					

Alternate Form:

PLOAD4	SID	E1	P1	P2	P3	P4	"THRU"	E2	ghi
PLOAD4	1001	452	105.				THRU	568	GHI

+hi	CID	N1	N2	N3					
+HI	2375	0.	1.	1.					

Field	Contents
SID	Load set identification number (Integer > 0)
EID,E1,E2	Element identification number (Integer > 0, E1 < E2)
Pi	Pressure at the grid point defining the element face (Real or blank)
CID	Coordinate system identification number (Integer > 0)
Ni	Components of a vector in system CID that defines the direction of the pressure (Real)

Remarks:

1. For the plate element QUAD4, if the continuation entry is not given, the direction of the pressure is normal to the element in the element Z direction. If only P1 is given, the pressure is assumed to be uniform over the element surface.

2. If the loaded surface of an element is curved, and a direction vector is not specified, the direction of the pressure may vary over the surface. The pressure intensity is the load per unit surface area.

3. Equivalent grid point loads are computed. A uniform pressure need not result in equal grid point loads.

Bulk Data Entry PSHELL   Shell Element Property

Description: Defines the membrane, bending, transverse shear, and coupling properties of the QUAD4 shell element.

Format and Example:

1	2	3	4	5	6	7	8	9	10
PSHELL	PID	MID1	T	MID2	12I/T³	MID3	TS/T	NSM	abc
PSHELL	203	204	1.90	205	1.2	206	0.8	6.32	ABC
+bc	Z1	Z2	MID4	MCSID	SCSID	Z0			
+BC	+.95	-.95		0	0	0.01			

Field	Contents
PID	Property identification number (Integer > 0)
MID1	Material identification number for membrane (Integer > 0 or blank)
T	Default value for membrane thickness (Real > 0.0)
MID2	Material identification number for bending (Integer > 0 or blank)
12I/T³	Bending stiffness parameter (Real or blank, default = 1.0)
MID3	Material identification number for transverse shear (Integer > 0 or blank, must be blank unless MID2 > 0)
TS/T	Transverse shear thickness divided by membrane thickness (Real or blank, default = .833333)
NSM	Nonstructural mass per unit area (Real)
Z1,Z2	Fiber distances for stress computation. The positive direction is determined by the righthand rule and the order in which the grid points are listed on the connection entry. (Real or blank, defaults are -T/2 for Z1 and +T/2 for Z2).
MID4	Material identification number for membrane-bending coupling (Integer > 0 or blank, must be blank unless MID1 > 0 and MID2 > 0, may not equal MID1 or MID2)
MCSID	Identification number of material coordinate system (Real or blank, or (Integer ≥ 0) (See Remark 11)
SCSID	Identification number of stress coordinate system (Real or blank, or (Integer ≥ 0) (See Remark 11)
Z0	Offset of the element reference plane from the plane of grid points. (Real or blank, default = 0.0) (See Remark 12)

(Continued)

Remarks:

1. All PSHELL property entries must have unique identification numbers.

2. The structural mass is computed from the density using the membrane thickness and membrane material properties.

3. The results of leaving any MID field blank are:

MID1	No membrane or coupling stiffness
MID2	No bending, coupling, or transverse shear stiffness
MID3	No transverse shear flexibility
MID4	No membrane-bending coupling

4. The continuation entry is not required.

5. Structural damping, when needed, is obtained from the MID1 material.

6. The MID4 field should be left blank if the material properties are symmetric with the middle surface of the shell.

7. For structural problems, PSHELL entries may reference MAT1, MAT2 or MAT8 material property data.

8. If the transverse shear material, MID3, references MAT2 data, then G33 must be zero. If MID3 references MAT8 data, then G1,Z and G2,Z must not be zero.

9. For heat transfer problems PSHELL entries may reference MAT4 or MAT5 material property data.

10. If MCSID/SCSID is left blank (0.0) or is real, it is considered to be the angle of rotation of the X axis of the material/stress coordinate system with respect to the X axis of the element coordinate system in the XY plane of the latter. If Integer, the orientation of the material/stress x-axis is along the projection of the x-axis of the specified coordinate system onto the x-y plane of the element system. The value of MCSID is the default value for the TM field on the CQUAD4 Bulk Data entries.

11. The value of ZO is the default value for the corresponding field on the CQUAD4 Bulk Data entries.

APPENDIX D: NASTRAN INPUT DATA FOR SAMPLE PROBLEMS 1-6, 8, 9, 11, 13c, 14

PROBLEM #1

```
ID MACNEAL,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND
MEMBRANE PLATE PATCH TEST                                   APRIL 12, 1988   RELEASE 1987 CDC   PAGE   2

                                   C A S E   C O N T R O L   D E C K   E C H O
              CARD
              COUNT
               1      TITLE = MEMBRANE PLATE PATCH TEST
               2      SPC = 1
               3      SPCFORCES = ALL
               4      DISP = ALL
               5      STRESS = ALL
               6      BEGIN BULK

*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
    MEMBRANE PLATE PATCH TEST                               APRIL 12, 1988   RELEASE 1987 CDC   PAGE   3

                                   S O R T E D   B U L K   D A T A   E C H O
              CARD
              COUNT        .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
               1-        CQUAD4  1       1       1       2       6       5
               2-        CQUAD4  2       1       2       3       7       6
               3-        CQUAD4  3       1       3       4       8       7
               4-        CQUAD4  4       1       1       5       8       4
               5-        CQUAD4  5       1       4       3       2       1
               6-        GRID    1               .04     .02     .0
               7-        GRID    2               .18     .03     .0
               8-        GRID    3               [illegible] .08 .0
               9-        GRID    4               .08     .08     .0
              10-        GRID    5               .0      .0      .0
              11-        GRID    6               .24     .0      .0
              12-        GRID    7               .24     .12     .0
              13-        GRID    8               .0      .12     .0
              14-        MAT1    1       1.0 E+06        .25
              15-        PSHELL  1       1       .001    1       1.0     1       1.0     .0
              16-        SPC     1       5       1       .0      5       2       .0
              17-        SPC     1       6       1       .00024  6       2       .00012
              18-        SPC     1       7       1       .00030  7       2       .00024
              19-        SPC     1       8       1       .00006  8       2       .00012
              20-        SPC1    1       6       1       THRU    8
                         ENDDATA
```

```
ID MASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND
1   BENDING PLATE PATCH TEST                                       APRIL  12, 1988    RELEASE  1987  CDC    PAGE     2

0
0                                 C A S E   C O N T R O L   D E C K   E C H O
              CARD
              COUNT
               1       TITLE = BENDING PLATE PATCH TEST
               2       SPC = 1
               3       SPCFORCES = ALL
               4       DISP = ALL
               5       STRESS = ALL
               6       BEGIN BULK
0
0*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1    BENDING PLATE PATCH TEST                                       APRIL  12, 1988    RELEASE  1987  CDC    PAGE     3

0
0                                      S O R T E D   B U L K   D A T A   E C H O
              CARD
              COUNT        .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
                1-        CQUAD4  1       1       1       2       6       5
                2-        CQUAD4  2       1       2       3       7       6
                3-        CQUAD4  3       1       3       4       8       7
                4-        CQUAD4  4       1       1       5       8       4
                5-        CQUAD4  5       1       4       3       2       1
                6-        GRID    1               .04     .02     .0
                7-        GRID    2               .18     .03     .0
                8-        GRID    3               .16     .08     .0
                9-        GRID    4               .08     .08     .0
               10-        GRID    5               .0      .0      .0
               11-        GRID    6               .24     .0      .0
               12-        GRID    7               .24     .12     .0
               13-        GRID    8               .0      .12     .0
               14-        MAT1    1       1.0 E+06        .25
               15-        PSHELL  1       1       .001    1       1.0     1       1.0     .0
               16-        SPC     1       5       3       .0      5       4       .0
               17-        SPC     1       5       5       .0
               18-        SPC     1       6       3       2.88E-006       4       .00012
               19-        SPC     1       6       5       -.00024
               20-        SPC     1       7       3       5.04E-007       4       .00024
               21-        SPC     1       7       5       -.00038
               22-        SPC     1       8       3       7.20E-008       4       .00012
               23-        SPC     1       8       5       -.00006
               24-        SPC1    1       5       1       THRU    8
                          ENDDATA
```

```
ID NASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 5
CEND
```

PROBLEM #2

0
0

C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
  1      TITLE = STRAIGHT CANTILEVER BEAM - REGULAR SHAPE ELEMENTS
  2      DISP = ALL
  3      STRESS = ALL
  4      ELFORCES = ALL
  5      STRAIN = ALL
  6      SPC = 1
  7      SPCFORCES = ALL
  8      OLOAD = ALL
  9      $LOAD IN THE X DIRECTION
 10         SUBCASE 1
 11           LOAD = 1
 12      $LOAD IN THE Z DIRECTION
 13         SUBCASE  2
 14           LOAD = 2
 15      $LOAD IN THE Y DIRECTION
 16         SUBCASE 3
 17           LOAD = 3
 18      $TWIST LOAD
 19         SUBCASE 4
 20           LOAD = 4
 21      BEGIN BULK
```

0
0*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.

0
0

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CQUAD4	1	1	1	3	4	2			
2-	CQUAD4	2	1	3	5	5	4			
3-	CQUAD4	3	1	5	7	8	6			
4-	CQUAD4	4	1	7	9	10	8			
5-	CQUAD4	5	1	9	11	12	10			
6-	CQUAD4	6	1	11	13	14	12			
7-	FORCE	1	13		.5	1.0	.0	.0		
8-	FORCE	1	14		.5	1.0	.0	.0		
9-	FORCE	2	13		-0.5	.0	.0	1.0		
10-	FORCE	2	14		-0.5	.0	.0	1.0		
11-	FORCE	3	13		.5	.0	1.0	.0		
12-	FORCE	3	14		.5	.0	1.0	.0		
13-	FORCE	4	13		-0.5	.0	.0	1.0		
14-	FORCE	4	14		.5	.0	.0	1.0		
15-	GRID	1		.0	.1	.0				
16-	GRID	2		.0	-0.1	.0				
17-	GRID	3		1.0	.1	.0				
18-	GRID	4		1.0	-0.1	.0				
19-	GRID	5		2.0	.1	.0				
20-	GRID	6		2.0	-0.1	.0				
21-	GRID	7		3.0	.1	.0				
22-	GRID	8		3.0	-0.1	.0				
23-	GRID	9		4.0	.1	.0				

```
24-    GRID    10                4.0     -0.1    .0
25-    GRID    11                5.0     .1      .0
26-    GRID    12                5.0     -0.1    .0
27-    GRID    13                6.0     .1      .0
28-    GRID    14                6.0     -0.1    .0
29-    MAT1    1       1.0 E+07          .3
30-    PSHELL  1       1         .3      1       1.0     1
31-    SPC1    1       5         3       THRU    14
32-    SPC1    1       123456    1       THRU    2
       ENDDATA
```

PROBLEM #2

```
ID NASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 560
CEND
1     STRAIGHT CANTILEVER BEAM - PARALLELOGRAM SHAPE ELEMENTS                    APRIL 11, 1988    RELEASE 1987 CDC    PAGE    2

                              C A S E   C O N T R O L   D E C K   E C H O
          CARD
          COUNT
            1      TITLE = STRAIGHT CANTILEVER BEAM - PARALLELOGRAM SHAPE ELEMENTS
            2      DISP = ALL
            3      STRESS = ALL
            4      OLOAD = ALL
            5      SPC = 1
            6      SPCFORCES = ALL
            7      $LOAD IN THE X DIRECTION
            8         SUBCASE 1
            9         LOAD = 1
           10      $LOAD IN THE Z DIRECTION
           11         SUBCASE 2
           12         LOAD = 2
           13      $LOAD IN THE Y DIRECTION
           14         SUBCASE 3
           15         LOAD = 3
           16      $TWIST LOAD
           17         SUBCASE 4
           18         LOAD = 4
           19      BEGIN BULK

*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1     STRAIGHT CANTILEVER BEAM - PARALLELOGRAM SHAPE ELEMENTS                    APRIL 11, 1988    RELEASE 1987 CDC    PAGE    3

                                    S O R T E D   B U L K   D A T A   E C H O
          CARD
          COUNT        .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
            1-         CQUAD4  1       1       1       3       4       2
            2-         CQUAD4  2       1       3       5       6       4
            3-         CQUAD4  3       1       5       7       8       6
            4-         CQUAD4  4       1       7       9       10      8
            5-         CQUAD4  5       1       9       11      12      10
            6-         CQUAD4  6       1       11      13      14      12
            7-         FORCE   1       13              .5      1.0     .0      .0
            8-         FORCE   1       14              .5      1.0     .0      .0
            9-         FORCE   2       13              -0.5    .5      .0      1.0
           10-         FORCE   2       14              -0.5    .0      .0      1.0
           11-         FORCE   3       13              .5      .0      1.0     .0
           12-         FORCE   3       14              .5      .0      1.0     .0
           13-         FORCE   4       13              -0.5    .0      .0      1.0
           14-         FORCE   4       14              .5      .0      .0      1.0
           15-         GRID    1               .0      .1      .0
           16-         GRID    2               .0      -0.1    .0
           17-         GRID    3               1.2     .1      .0
           18-         GRID    4               1.0     -0.1    .0
           19-         GRID    5               2.2     .1      .0
           20-         GRID    6               2.0     -0.1    .0
           21-         GRID    7               3.2     .1      .0
           22-         GRID    8               3.0     -0.1    .0
           23-         GRID    9               4.2     .1      .0
           24-         GRID    10              4.0     -0.1    .0
           25-         GRID    11              5.2     .1      .0
```

PROBLEM #2

```
GRID    12              5.0     -0.1    .0
GRID    13              6.0     .1      .0
GRID    14              6.0     -0.1    .0
MAT1    1       1.0 E+07        .3
PSHELL  1       1       .1      1       1.0     1       1.0     .0
SPC1    1       6       3       THRU    14
SPC1    1       123456  1       THRU    2
ENDDATA
```

```
ID NASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 520
CEND
```

PROBLEM #2

STRAIGHT CANTILEVER BEAM - TRAPEZOIDAL SHAPE ELEMENTS   APRIL 21, 1988   RELEASE 1987 CDC   PAGE 2

C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
  1      TITLE = STRAIGHT CANTILEVER BEAM - TRAPEZOIDAL SHAPE ELEMENTS
  2      DISP = ALL
  3      OLOAD = ALL
  4      STRESS = ALL
  5      STRAIN = ALL
  6      SPC = 1
  7      SPCFORCES = ALL
  8      $LOAD IN THE X DIRECTION
  9         SUBCASE 1
 10         LOAD = 1
 11      $LOAD IN THE Z DIRECTION
 12         SUBCASE 2
 13         LOAD = 2
 14      $LOAD IN THE Y DIRECITON
 15         SUBCASE 3
 16         LOAD = 3
 17      $TWIST LOAD
 18         SUBCASE 4
 19         LOAD = 4
 20      BEGIN BULK
```

USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.

STRAIGHT CANTILEVER BEAM - TRAPEZOIDAL SHAPE ELEMENTS   APRIL 21, 1988   RELEASE 1987 CDC   PAGE 3

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CQUAD4	1	1	1	3	4	2			
2-	CQUAD4	2	1	3	5	6	4			
3-	CQUAD4	3	1	5	7	8	6			
4-	CQUAD4	4	1	7	9	10	8			
5-	CQUAD4	5	1	9	11	12	10			
6-	CQUAD4	6	1	11	13	14	12			
7-	FORCE	1	13		.5	1.0	.0	.0		
8-	FORCE	1	14		.5	1.0	.0	.0		
9-	FORCE	2	13		-0.5	.0	.0	1.0		
10-	FORCE	2	14		-0.5	.0	.0	1.0		
11-	FORCE	3	13		.5	.0	1.0	.0		
12-	FORCE	3	14		.5	.0	1.0	.0		
13-	FORCE	4	13		-0.5	.0	.0	1.0		
14-	FORCE	4	14		.5	.0	.0	1.0		
15-	GRID	1		.0	.1	.0				
16-	GRID	2		.0	-0.1	.0				
17-	GRID	3		.8	.1	.0				
18-	GRID	4		1.9	-0.1	.0				
19-	GRID	5		2.2	.1	.0				
20-	GRID	6		2.6	-0.1	.0				
21-	GRID	7		2.8	.1	.0				
22-	GRID	8		3.9	-0.1	.0				
23-	GRID	9		4.2	.1	.0				
24-	GRID	10		4.8	-0.1	.0				

PROBLEM #2

```
25-     GRID    11              4.0     .1      .0
26-     GRID    12              5.0     -0.1    .0
27-     GRID    13              6.0     .1      .0
28-     GRID    14              6.0     -0.1    .0
29-     MAT1    1       1.0 E+07        .3
30-     PSHELL  1       1       .1      1       1.0     1       1.0     .0
31-     SPC1    1       6       3       THRU    14
32-     SPC1    1       123456  1       THRU    2
        ENDDATA
```

PROBLEM #3

```
ID  MASTMAN,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND
1     CURVED BEAM                                              APRIL  12, 1988    RELEASE  1987  CDC    PAGE    2
0
0
                                  C A S E   C O N T R O L   D E C K   E C H O
             CARD
             COUNT
               1      TITLE = CURVED BEAM
               2      DISP = ALL
               3      SPCFORCES = ALL
               4      STRESS = ALL
               5      OLOAD = ALL
               6      SPC = 1
               7      $LOAD IN THE Y DIRECTION
               8        SUBCASE 1
               9        LOAD = 1
              10      $LOAD IN THE Z DIRECTION
              11        SUBCASE 2
              12        LOAD = 2
              13      BEGIN BULK
0
0*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1     CURVED BEAM                                              APRIL  12, 1988    RELEASE  1987  CDC    PAGE    3
0
0
                                              S O R T E D   B U L K   D A T A   E C H O
             CARD
             COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
               1-         CQUAD4  1       1       1       3       4       2
               2-         CQUAD4  2       1       3       5       6       4
               3-         CQUAD4  3       1       5       7       8       6
               4-         CQUAD4  4       1       7       9       10      8
               5-         CQUAD4  5       1       9       11      12      10
               6-         CQUAD4  6       1       11      13      14      12
               7-         FORCE   1       13              .5      .0      1.0     .0
               8-         FORCE   1       14              .5      .0      1.0     .0
               9-         FORCE   2       13              .5      .0      .0      1.0
              10-         FORCE   2       14              .5      .0      .0      1.0
              11-         GRID    1               4.12    .0      .0
              12-         GRID    2               4.32    .0      .0
              13-         GRID    3               3.9796  1.0663  .0
              14-         GRID    4               4.1728  1.1181  .0
              15-         GRID    5               3.5680  2.060   .0
              16-         GRID    6               3.7412  2.16    .0
              17-         GRID    7               2.9133  2.9133  .0
              18-         GRID    8               3.0547  3.0547  .0
              19-         GRID    9               2.060   3.5680  .0
              20-         GRID    10              2.160   3.7412  .0
              21-         GRID    11              1.0663  3.9796  .0
              22-         GRID    12              1.1181  4.1728  .0
              23-         GRID    13              .0      4.12    .0
              24-         GRID    14              .0      4.32    .0
              25-         MAT1    1       1.0 E+07        .25
              26-         PSHELL  1       1       .1      1       1.0     1       1.0     .0
              27-         SPC1    1       2       3       THRU    14
              28-         SPC1    1       123456  1       THRU    2
                          ENDDATA
```

```
ID NASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND                                                                    APRIL 12, 1988   RELEASE 1987 CDC   PAGE   2
1   TWISTED BEAM

0                               C A S E   C O N T R O L   D E C K   E C H O
0
            CARD
            COUNT
             1        TITLE = TWISTED BEAM
             2        SPC = 5
             3        SPCFORCES = ALL
             4        OLOAD = ALL
             5        DISP = ALL
             6        STRESS = ALL
             7        SUBCASE 1
             8            LOAD = 1
             9        SUBCASE 2
            10            LOAD = 2
            11        BEGIN BULK
0
0*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
                                                                        APRIL 12, 1988   RELEASE 1987 CDC   PAGE   3
1   TWISTED BEAM

0                                 S O R T E D   B U L K   D A T A   E C H O
0
            CARD
            COUNT    .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
               1-    CQUAD4  1       20      39      38      36      36      .000
               2-    CQUAD4  2       20      38      37      34      35      .000
               3-    CQUAD4  3       20      36      35      32      33      .000
               4-    CQUAD4  4       20      35      34      31      32      .000
               5-    CQUAD4  5       20      33      32      29      30      .000
               6-    CQUAD4  6       20      32      31      28      29      .000
               7-    CQUAD4  7       20      30      29      26      27      .000
               8-    CQUAD4  8       20      29      28      25      26      .000
               9-    CQUAD4  9       20      27      26      23      24      .000
              10-    CQUAD4  10      20      26      25      22      23      .000
              11-    CQUAD4  11      20      24      23      20      21      .000
              12-    CQUAD4  12      20      23      22      19      20      .000
              13-    CQUAD4  13      20      21      20      17      18      .000
              14-    CQUAD4  14      20      20      19      16      17      .000
              15-    CQUAD4  15      20      18      17      14      15      .000
              16-    CQUAD4  16      20      17      16      13      14      .000
              17-    CQUAD4  17      20      15      14      11      12      .000
              18-    CQUAD4  18      20      14      13      10      11      .000
              19-    CQUAD4  19      20      12      11      8       9       .000
              20-    CQUAD4  20      20      11      10      7       8       .000
              21-    CQUAD4  21      20      9       8       5       6       .000
              22-    CQUAD4  22      20      8       7       4       5       .000
              23-    CQUAD4  23      20      6       5       2       3       .000
              24-    CQUAD4  24      20      5       4       1       2       .000
              25-    FORCE   1       1               .5      1.0     .0      .0
              26-    FORCE   1       3               .5      1.0     .0      .0
              27-    FORCE   2       1               -0.5    .0      1.0     .0
              28-    FORCE   2       3               -0.5    .0      1.0     .0
              29-    GRID    1               .54987  0.0     12.0000
              30-    GRID    2               0.0     0.0     12.0000
              31-    GRID    3               -.54987 0.0     12.0000
              32-    GRID    4               .54527  -.07176 11.0000
              33-    GRID    5               0.0     0.0     11.0000
```

PROBLEM #4

```
                   34-        GRID    6                  -.54527 .07176  11.0000
1    TWISTED BEAM                                                                   APRIL  12, 1988    RELEASE  1987  CDC     PAGE     4
0
0                                                  S O R T E D   B U L K   D A T A   E C H O
                 CARD
                 COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
                   35-        GRID    7                   .53124  -.14232 10.0000
                   36-        GRID    8                   0.0     0.0     10.0000
                   37-        GRID    9                   -.53124 .14232  10.0000
                   38-        GRID    10                  .50812  -.21043 9.00000
                   39-        GRID    11                  0.0     0.0     9.00000
                   40-        GRID    12                  -.50812 .21045  9.00000
                   41-        GRID    13                  .47631  -.27497 8.00000
                   42-        GRID    14                  0.0     0.0     8.00000
                   43-        GRID    15                  -.47631 .27497  8.00000
                   44-        GRID    16                  .43634  -.33480 7.00000
                   45-        GRID    17                  0.0     0.0     7.00000
                   46-        GRID    18                  -.43634 .33480  7.00000
                   47-        GRID    19                  .38891  -.38889 6.00000
                   48-        GRID    20                  0.0     0.0     6.00000
                   49-        GRID    21                  -.38891 .38889  6.00000
                   50-        GRID    22                  .33482  -.43633 5.00000
                   51-        GRID    23                  0.0     0.0     5.00000
                   52-        GRID    24                  -.33482 .43633  5.00000
                   53-        GRID    25                  .27500  -.47630 4.00000
                   54-        GRID    26                  0.0     0.0     4.00000
                   55-        GRID    27                  -.27500 .47630  4.00000
                   56-        GRID    28                  .21048  -.50812 3.00000
                   57-        GRID    29                  0.0     0.0     3.00000
                   58-        GRID    30                  -.21048 .50812  3.00000
                   59-        GRID    31                  .14235  -.53125 2.00000
                   60-        GRID    32                  0.0     0.0     2.00000
                   61-        GRID    33                  -.14235 .53125  2.00000
                   62-        GRID    34                  .07179  -.54529 1.00000
                   63-        GRID    35                  0.0     0.0     1.00000
                   64-        GRID    36                  -.07179 .54529  1.00000
                   65-        GRID    37                  0.0     -.55000 0.0
                   66-        GRID    38                  0.0     0.0     0.0
                   67-        GRID    39                  0.0     .55000  0.0
                   68-        MAT1    10          2.900+7 1.189+7 .22000  0.0     0.0     0.0     0.0     +M      1
1    TWISTED BEAM                                                                   APRIL  12, 1988    RELEASE  1987  CDC     PAGE     5
0
0                                                  S O R T E D   B U L K   D A T A   E C H O
                 CARD
                 COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
                   69-        +M      1 0.        0.      0.
                   70-        PARAM   AUTOSPC 1
                   71-        PSHELL  20      10      .32     10      1.0     10      1.0     .0
                   72-        SPC1    5       6       1       THRU    38
                   73-        SPC1    5       123456  37      38      39
                              ENDDATA
```

APPLICATION OF SINGLE POINT CONSTRAINTS. REFER TO PRINTOUT OF AUTOMATICALLY GENERATED SPC1 CARDS FOR DETAILS.
1 TWISTED BEAM APRIL 12, 1988 RELEASE 1987 CDC PAGE 7

A U T O M A T I C A L L Y G E N E R A T E D S P C 1 C A R D S

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	SPC1	5	4	23	26	29	32	35		
2-	SPC1	5	6	2	5	8	11	14	17	
3-	SPC1	5	5	20						

```
     ID NASTRAN,TISCHLER
     APP DISP
     SOL 1,0
     TIME 500
     CEND
1     RECTANGULAR PLATE - CLAMPED AR=1  N=6                              APRIL  13, 1988    RELEASE  1987  CDC     PAGE     2
0
0                                        C A S E   C O N T R O L   D E C K   E C H O
                 CARD
                 COUNT
                   1       TITLE = RECTANGULAR PLATE - CLAMPED AR=1  N=6
                   2       DISP = ALL
                   3       STRESS = ALL
                   4       OLOAD = ALL
                   5       SPCFORCES = ALL
                   6       SPC = 5
                   7       SUBCASE 1
                   8       $ UNIFORM PRESSURE
                   9          LOAD = 1
                  10       SUBCASE 2
                  11       $ CENTRAL LOAD
                  12          LOAD = 2
                  13       BEGIN BULK
0
0*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1     RECTANGULAR PLATE - CLAMPED AR=1  N=6                              APRIL  13, 1988    RELEASE  1987  CDC     PAGE     3
0
0                                              S O R T E D   B U L K   D A T A   E C H O
                 CARD
                 COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
                   1-        CQUAD4  1        1        1        2        9        8
                   2-        CQUAD4  2        1        2        3        10       9
                   3-        CQUAD4  3        1        3        4        11       10
                   4-        CQUAD4  4        1        4        5        12       11
                   5-        CQUAD4  5        1        5        6        13       12
                   6-        CQUAD4  6        1        6        7        14       13
                   7-        CQUAD4  7        1        8        9        16       15
                   8-        CQUAD4  8        1        9        10       17       16
                   9-        CQUAD4  9        1        10       11       18       17
                  10-        CQUAD4  10       1        11       12       19       18
                  11-        CQUAD4  11       1        12       13       20       19
                  12-        CQUAD4  12       1        13       14       21       20
                  13-        CQUAD4  13       1        15       16       23       22
                  14-        CQUAD4  14       1        16       17       24       23
                  15-        CQUAD4  15       1        17       18       25       24
                  16-        CQUAD4  16       1        18       19       26       25
                  17-        CQUAD4  17       1        19       20       27       26
                  18-        CQUAD4  18       1        20       21       28       27
                  19-        CQUAD4  19       1        22       23       30       29
                  20-        CQUAD4  20       1        23       24       31       30
                  21-        CQUAD4  21       1        24       25       32       31
                  22-        CQUAD4  22       1        25       26       33       32
                  23-        CQUAD4  23       1        26       27       34       33
                  24-        CQUAD4  24       1        27       28       35       34
                  25-        CQUAD4  25       1        29       30       37       36
                  26-        CQUAD4  26       1        30       31       38       37
                  27-        CQUAD4  27       1        31       32       39       38
                  28-        CQUAD4  28       1        32       33       40       39
                  29-        CQUAD4  29       1        33       34       41       40
                  30-        CQUAD4  30       1        34       35       42       41
                  31-        CQUAD4  31       1        36       37       44       43
```

```
        32-        CQUAD4  32       1        37       38       45       44
        33-        CQUAD4  33       1        38       39       46       45
        34-        CQUAD4  34       1        39       40       47       46
1   RECTANGULAR PLATE - CLAMPED AR=1  N=6                        APRIL  13, 1988    RELEASE  1987  CDC    PAGE     4
0
0                                          S O R T E D   B U L K   D A T A   E C H O
      CARD
      COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
        35-        CQUAD4  35       1        40       41       48       47
        36-        CQUAD4  36       1        41       42       49       48
        37-        FORCE   2        49                -1.0E-04.0        .0       1.0
        38-        GRID    1                 .0000    .0000    .0000
        39-        GRID    2                 .0000    .1667    .0000
        40-        GRID    3                 .0000    .3333    .0000
        41-        GRID    4                 .0000    .5000    .0000
        42-        GRID    5                 .0000    .6667    .0000
        43-        GRID    6                 .0000    .8333    .0000
        44-        GRID    7                 .0000    1.0000   .0000
        45-        GRID    8                 .1667    .0000    .0000
        46-        GRID    9                 .1667    .1667    .0000
        47-        GRID    10                .1667    .3333    .0000
        48-        GRID    11                .1667    .5000    .0000
        49-        GRID    12                .1667    .6667    .0000
        50-        GRID    13                .1667    .8333    .0000
        51-        GRID    14                .1667    1.0000   .0000
        52-        GRID    15                .3333    .0000    .0000
        53-        GRID    16                .3333    .1667    .0000
        54-        GRID    17                .3333    .3333    .0000
        55-        GRID    18                .3333    .5000    .0000
        56-        GRID    19                .3333    .6667    .0000
        57-        GRID    20                .3333    .8333    .0000
        58-        GRID    21                .3333    1.0000   .0000
        59-        GRID    22                .5000    .0000    .0000
        60-        GRID    23                .5000    .1667    .0000
        61-        GRID    24                .5000    .3333    .0000
        62-        GRID    25                .5000    .5000    .0000
        63-        GRID    26                .5000    .6667    .0000
        64-        GRID    27                .5000    .8333    .0000
        65-        GRID    28                .5000    1.0000   .0000
        66-        GRID    29                .6667    .0000    .0000
        67-        GRID    30                .6667    .1667    .0000
        68-        GRID    31                .6667    .3333    .0000
1   RECTANGULAR PLATE - CLAMPED AR=1  N=6                        APRIL  13, 1988    RELEASE  1987  CDC    PAGE     5
0
0                                          S O R T E D   B U L K   D A T A   E C H O
      CARD
      COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
        69-        GRID    32                .6667    .5000    .0000
        70-        GRID    33                .6667    .6667    .0000
        71-        GRID    34                .6667    .8333    .0000
        72-        GRID    35                .6667    1.0000   .0000
        73-        GRID    36                .8333    .0000    .0000
        74-        GRID    37                .8333    .1667    .0000
        75-        GRID    38                .8333    .3333    .0000
        76-        GRID    39                .8333    .5000    .0000
        77-        GRID    40                .8333    .6667    .0000
        78-        GRID    41                .8333    .8333    .0000
        79-        GRID    42                .8333    1.0000   .0000
        80-        GRID    43                1.0000   .0000    .0000
        81-        GRID    44                1.0000   .1667    .0000
        82-        GRID    45                1.0000   .3333    .0000
```

```
GRID    46              1.0000  .5000   .0000
GRID    47              1.0000  .6667   .0000
GRID    48              1.0000  .8333   .0000
GRID    49              1.0000  1.0000  .0000
MAT1    1       1.747227        .3
PLOAD2  1       [illegible] 1   THRU    36
PSHELL  1       1       .001    1       1.0     1       1.0     .6
SPC1    5       6       9       THRU    14
SPC1    5       6       16      THRU    21
SPC1    5       6       23      THRU    28
SPC1    5       6       30      THRU    35
SPC1    5       6       37      THRU    42
SPC1    5       6       44      THRU    49
SPC1    5       15      44      45      46      47      48      49
SPC1    5       24      14      21      28      35      42      49
SPC1    5       123456  1       2       3       4       5       6
SPC1    5       123456  7       8       15      22      29      36
SPC1    5       123456  43
ENDDATA
```

```
ID NASTRAN,TIS..LER
APP DISP
SOL 1,0
TIME 500
CEND
1    RECTANGULAR PLATE - CLAMPED AR=5  N=6                          APRIL 13, 1988   RELEASE 1987 CDC    PAGE    2

0
0                                C A S E   C O N T R O L   D E C K   E C H O
              CARD
              COUNT
                1      TITLE = RECTANGULAR PLATE - CLAMPED AR=5  N=6
                2      DISP = ALL
                3      STRESS = ALL
                4      OLOAD = ALL
                5      SPCFORCES = ALL
                6      SPC = 5
                7      SUBCASE 1
                8      $ UNIFORM PRESSURE
                9         LOAD = 1
               10      SUBCASE 2
               11      $ CENTRAL LOAD
               12         LOAD = 2
               13      BEGIN BULK
0
*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1     RECTANGULAR PLATE - CLAMPED AR=5  N=6                        APRIL 13, 1988   RELEASE 1987 CDC    PAGE    3

0
0                                   S O R T E D   B U L K   D A T A   E C H O
              CARD
              COUNT         .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
```

CARD COUNT	1	2	3	4	5	6	7
1-	CQUAD4	1	1	1	2	9	8
2-	CQUAD4	2	1	2	3	10	9
3-	CQUAD4	3	1	3	4	11	10
4-	CQUAD4	4	1	4	5	12	11
5-	CQUAD4	5	1	5	6	13	12
6-	CQUAD4	6	1	6	7	14	13
7-	CQUAD4	7	1	8	9	16	15
8-	CQUAD4	8	1	9	10	17	16
9-	CQUAD4	9	1	10	11	18	17
10-	CQUAD4	10	1	11	12	19	18
11-	CQUAD4	11	1	12	13	20	19
12-	CQUAD4	12	1	13	14	21	20
13-	CQUAD4	13	1	15	16	23	22
14-	CQUAD4	14	1	16	17	24	23
15-	CQUAD4	15	1	17	18	25	24
16-	CQUAD4	16	1	18	19	26	25
17-	CQUAD4	17	1	19	20	27	26
18-	CQUAD4	18	1	20	21	28	27
19-	CQUAD4	19	1	22	23	30	29
20-	CQUAD4	20	1	23	24	31	30
21-	CQUAD4	21	1	24	25	32	31
22-	CQUAD4	22	1	25	26	33	32
23-	CQUAD4	23	1	26	27	34	33
24-	CQUAD4	24	1	27	28	35	34
25-	CQUAD4	25	1	29	30	37	36
26-	CQUAD4	26	1	30	31	38	37
27-	CQUAD4	27	1	31	32	39	38
28-	CQUAD4	28	1	32	33	40	39
29-	CQUAD4	29	1	33	34	41	40
30-	CQUAD4	30	1	34	35	42	41
31-	CQUAD4	31	1	36	37	44	43

PROBLEM #5

```
              32-        CQUAD4   32      1       37      38      45      44
              33-        CQUAD4   33      1       38      39      46      45
              34-        CQUAD4   34      1       39      40      47      46
1   RECTANGULAR PLATE - CLAMPED AR=5  N=6                         APRIL 13, 1988    RELEASE 1987 CDC    PAGE    4

                                          S O R T E D   B U L K   D A T A   E C H O
            CARD
            COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
              35-        CQUAD4   35      1       40      41      48      47
              36-        CQUAD4   36      1       41      42      49      48
              37-        FORCE    2       49              -1.0E-04.0      .0      1.0
              38-        GRID     1               .0000   .0000   .0000
              39-        GRID     2               .0000   .1667   .0000
              40-        GRID     3               .0000   .3333   .0000
              41-        GRID     4               .0000   .5000   .0000
              42-        GRID     5               .0000   .6667   .0000
              43-        GRID     6               .0000   .8333   .0000
              44-        GRID     7               .0000   1.0000  .0000
              45-        GRID     8               .8333   .0000   .0000
              46-        GRID     9               .8333   .1667   .0000
              47-        GRID     10              .8333   .3333   .0000
              48-        GRID     11              .8333   .5000   .0000
              49-        GRID     12              .8333   .6667   .0000
              50-        GRID     13              .8333   .8333   .0000
              51-        GRID     14              .8333   1.0000  .0000
              52-        GRID     15              1.6667  .0000   .0000
              53-        GRID     16              1.6667  .1667   .0000
              54-        GRID     17              1.6667  .3333   .0000
              55-        GRID     18              1.6667  .5000   .0000
              56-        GRID     19              1.6667  .6667   .0000
              57-        GRID     20              1.6667  .8333   .0000
              58-        GRID     21              1.6667  1.0000  .0000
              59-        GRID     22              2.5000  .0000   .0000
              60-        GRID     23              2.5000  .1667   .0000
              61-        GRID     24              2.5000  .3333   .0000
              62-        GRID     25              2.5000  .5000   .0000
              63-        GRID     26              2.5000  .6667   .0000
              64-        GRID     27              2.5000  .8333   .0000
              65-        GRID     28              2.5000  1.0000  .0000
              66-        GRID     29              3.3333  .0000   .0000
              67-        GRID     30              3.3333  .1667   .0000
              68-        GRID     31              3.3333  .3333   .0000
1   RECTANGULAR PLATE - CLAMPED AR=5  N=6                         APRIL 13, 1988    RELEASE 1987 CDC    PAGE    5

                                          S O R T E D   B U L K   D A T A   E C H O
            CARD
            COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
              69-        GRID     32              3.3333  .5000   .0000
              70-        GRID     33              3.3333  .6667   .0000
              71-        GRID     34              3.3333  .8333   .0000
              72-        GRID     35              3.3333  1.0000  .0000
              73-        GRID     36              4.1667  .0000   .0000
              74-        GRID     37              4.1667  .1667   .0000
              75-        GRID     38              4.1667  .3333   .0000
              76-        GRID     39              4.1667  .5000   .0000
              77-        GRID     40              4.1667  .6667   .0000
              78-        GRID     41              4.1667  .8333   .0000
              79-        GRID     42              4.1667  1.0000  .0000
              80-        GRID     43              5.0000  .0000   .0000
              81-        GRID     44              5.0000  .1667   .0000
              82-        GRID     45              5.0000  .3333   .0000
```

PROBLEM #5

```
83-        GRID    46                      5.0000  .5000   .0000
84-        GRID    47                      5.0000  .6667   .0000
85-        GRID    48                      5.0000  .8333   .0000
86-        GRID    49                      5.0000  1.0000  .0000
87-        MAT1    1       1.7472E7                .3
88-        PLOAD2  1       1.0E-04 1       THRU    36
89-        PSHELL  1       1       .001    1       1.0     1       1.0     .8
90-        SPC1    5       6       9       THRU    14
91-        SPC1    5       6       16      THRU    21
92-        SPC1    5       6       23      THRU    28
93-        SPC1    5       6       30      THRU    35
94-        SPC1    5       6       37      THRU    42
95-        SPC1    5       6       44      THRU    49
96-        SPC1    5       15      44      45      46      47      48      49
97-        SPC1    5       24      14      21      28      35      42      49
98-        SPC1    5       123456  1       2       3       4       5       6
99-        SPC1    5       123456  7       8       15      22      29      36
100-       SPC1    5       123456  43
           ENDDATA
```

```
ID NASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND
1     RECTANGULAR PLATE - SIMPLY SUPPORTED AR=1  N=6                APRIL 13, 1980    RELEASE 1987 CDC    PAGE    2

0
0                            C A S E   C O N T R O L   D E C K   E C H O
            CARD
            COUNT
             1      TITLE = RECTANGULAR PLATE - SIMPLY SUPPORTED AR=1  N=6
             2      DISP = ALL
             3      STRESS = ALL
             4      OLOAD = ALL
             5      SPCFORCES = ALL
             6      SPC = 5
             7      SUBCASE 1
             8      $ UNIFORM PRESSURE
             9         LOAD = 1
            10      SUBCASE 2
            11      $ CENTRAL LOAD
            12         LOAD = 2
            13      BEGIN BULK
0
0*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1     RECTANGULAR PLATE - SIMPLY SUPPORTED AR=1  N=6                APRIL 13, 1980    RELEASE 1987 CDC    PAGE    3

0
0                                 S O R T E D   B U L K   D A T A   E C H O
            CARD
            COUNT        .   1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
              1-        CQUAD4   1       1       1       2       9       8
              2-        CQUAD4   2       1       2       3       10      9
              3-        CQUAD4   3       1       3       4       11      10
              4-        CQUAD4   4       1       4       5       12      11
              5-        CQUAD4   5       1       5       6       13      12
              6-        CQUAD4   6       1       6       7       14      13
              7-        CQUAD4   7       1       8       9       16      15
              8-        CQUAD4   8       1       9       10      17      16
              9-        CQUAD4   9       1       10      11      18      17
             10-        CQUAD4   10      1       11      12      19      18
             11-        CQUAD4   11      1       12      13      20      19
             12-        CQUAD4   12      1       13      14      21      20
             13-        CQUAD4   13      1       15      16      23      22
             14-        CQUAD4   14      1       16      17      24      23
             15-        CQUAD4   15      1       17      18      25      24
             16-        CQUAD4   16      1       18      19      26      25
             17-        CQUAD4   17      1       19      20      27      26
             18-        CQUAD4   18      1       20      21      28      27
             19-        CQUAD4   19      1       22      23      30      29
             20-        CQUAD4   20      1       23      24      31      30
             21-        CQUAD4   21      1       24      25      32      31
             22-        CQUAD4   22      1       25      26      33      32
             23-        CQUAD4   23      1       26      27      34      33
             24-        CQUAD4   24      1       27      28      35      34
             25-        CQUAD4   25      1       29      30      37      36
             26-        CQUAD4   26      1       30      31      38      37
             27-        CQUAD4   27      1       31      32      39      38
             28-        CQUAD4   28      1       32      33      40      39
             29-        CQUAD4   29      1       33      34      41      40
             30-        CQUAD4   30      1       34      35      42      41
             31-        CQUAD4   31      1       36      37      44      43
```

```
         32-        CQUAD4  32      1       37      38      45      44
         33-        CQUAD4  33      1       38      39      46      45
         34-        CQUAD4  34      1       39      40      47      46
1   RECTANGULAR PLATE - SIMPLY SUPPORTED AR=1  N=6                 APRIL 13, 1988   RELEASE 1987 CDC   PAGE    4
0
0                                     S O R T E D   B U L K   D A T A   E C H O
        CARD
        COUNT       .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
         35-        CQUAD4  35      1       40      41      48      47
         36-        CQUAD4  36      1       41      42      49      48
         37-        FORCE   2       49              -1.0E-04.0      .0      1.0
         38-        GRID    1               .0000   .0000   .0000
         39-        GRID    2               .0000   .1667   .0000
         40-        GRID    3               .0000   .3333   .0000
         41-        GRID    4               .0000   .5000   .0000
         42-        GRID    5               .0000   .6667   .0000
         43-        GRID    6               .0000   .8333   .0000
         44-        GRID    7               .0000   1.0000  .0000
         45-        GRID    8               .1667   .0000   .0000
         46-        GRID    9               .1667   .1667   .0000
         47-        GRID    10              .1667   .3333   .0000
         48-        GRID    11              .1667   .5000   .0000
         49-        GRID    12              .1667   .6667   .0000
         50-        GRID    13              .1667   .8333   .0000
         51-        GRID    14              .1667   1.0000  .0000
         52-        GRID    15              .3333   .0000   .0000
         53-        GRID    16              .3333   .1667   .0000
         54-        GRID    17              .3333   .3333   .0000
         55-        GRID    18              .3333   .5000   .0000
         56-        GRID    19              .3333   .6667   .0000
         57-        GRID    20              .3333   .8333   .0000
         58-        GRID    21              .3333   1.0000  .0000
         59-        GRID    22              .5000   .0000   .0000
         60-        GRID    23              .5000   .1667   .0000
         61-        GRID    24              .5000   .3333   .0000
         62-        GRID    25              .5000   .5000   .0000
         63-        GRID    26              .5000   .6667   .0000
         64-        GRID    27              .5000   .8333   .0000
         65-        GRID    28              .5000   1.0000  .0000
         66-        GRID    29              .6667   .0000   .0000
         67-        GRID    30              .6667   .1667   .0000
         68-        GRID    31              .6667   .3333   .0000
1   RECTANGULAR PLATE - SIMPLY SUPPORTED AR=1  N=6                 APRIL 13, 1988   RELEASE 1987 CDC   PAGE    5
0
0                                     S O R T E D   B U L K   D A T A   E C H O
        CARD
        COUNT       .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
         69-        GRID    32              .6667   .5000   .0000
         70-        GRID    33              .6667   .6667   .0000
         71-        GRID    34              .6667   .8333   .0000
         72-        GRID    35              .6667   1.0000  .0000
         73-        GRID    36              .8333   .0000   .0000
         74-        GRID    37              .8333   .1667   .0000
         75-        GRID    38              .8333   .3333   .0000
         76-        GRID    39              .8333   .5000   .0000
         77-        GRID    40              .8333   .6667   .0000
         78-        GRID    41              .8333   .8333   .0000
         79-        GRID    42              .8333   1.0000  .0000
         80-        GRID    43              1.0000  .0000   .0000
         81-        GRID    44              1.0000  .1667   .0000
         82-        GRID    45              1.0000  .3333   .0000
```

```
GRID    46              1.0000  .5000   .0000
GRID    47              1.0000  .6667   .0000
GRID    48              1.0000  .8333   .0000
GRID    49              1.0000  1.0000  .0000
MAT1    1       1.7472E7        .3
PLOAD2  1       1.0E-04 1       THRU    36
PSHELL  1       1       .001    1       1.0     1       1.0     .0
SPC1    5       6       9       THRU    14
SPC1    5       6       16      THRU    21
SPC1    5       6       23      THRU    28
SPC1    5       6       30      THRU    35
SPC1    5       6       37      THRU    42
SPC1    5       6       44      THRU    49
SPC1    5       15      44      45      46      47      48      49
SPC1    5       24      14      21      28      35      42      49
SPC1    5       1236    1       2       3       4       5       6
SPC1    5       1236    7       8       15      22      29      36
SPC1    5       1236    43
ENDDATA
```

PROBLEM #5

```
ID MYSTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND
1    RECTANGULAR PLATE - SIMPLY SUPPORTED AR=5  N=6                 APRIL 13, 1988   RELEASE 1987 CDC   PAGE   2
0
0                                     C A S E   C O N T R O L   D E C K   E C H O
           CARD
           COUNT
             1      TITLE = RECTANGULAR PLATE - SIMPLY SUPPORTED AR=5  N=6
             2      DISP = ALL
             3      STRESS = ALL
             4      OLOAD = ALL
             5      SPCFORCES = ALL
             6      SPC = 5
             7      SUBCASE 1
             8      $ UNIFORM PRESSURE
             9        LOAD = 1
            10      SUBCASE 2
            11      $ CENTRAL LOAD
            12        LOAD = 2
            13      BEGIN BULK
0
     USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1    RECTANGULAR PLATE - SIMPLY SUPPORTED AR=5  N=6                 APRIL 13, 1988   RELEASE 1987 CDC   PAGE   3
0
0                                          S O R T E D   B U L K   D A T A   E C H O
           CARD
           COUNT        .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
             1-         CQUAD4  1     1     1     2     9     8
             2-         CQUAD4  2     1     2     3     10    9
             3-         CQUAD4  3     1     3     4     11    10
             4-         CQUAD4  4     1     4     5     12    11
             5-         CQUAD4  5     1     5     6     13    12
             6-         CQUAD4  6     1     6     7     14    13
             7-         CQUAD4  7     1     8     9     16    15
             8-         CQUAD4  8     1     9     10    17    16
             9-         CQUAD4  9     1     10    11    18    17
            10-         CQUAD4  10    1     11    12    19    18
            11-         CQUAD4  11    1     12    13    20    19
            12-         CQUAD4  12    1     13    14    21    20
            13-         CQUAD4  13    1     15    16    23    22
            14-         CQUAD4  14    1     16    17    24    23
            15-         CQUAD4  15    1     17    18    25    24
            16-         CQUAD4  16    1     18    19    26    25
            17-         CQUAD4  17    1     19    20    27    26
            18-         CQUAD4  18    1     20    21    28    27
            19-         CQUAD4  19    1     22    23    30    29
            20-         CQUAD4  20    1     23    24    31    30
            21-         CQUAD4  21    1     24    25    32    31
            22-         CQUAD4  22    1     25    26    33    32
            23-         CQUAD4  23    1     26    27    34    33
            24-         CQUAD4  24    1     27    28    35    34
            25-         CQUAD4  25    1     29    30    37    36
            26-         CQUAD4  26    1     30    31    38    37
            27-         CQUAD4  27    1     31    32    39    38
            28-         CQUAD4  28    1     32    33    40    39
            29-         CQUAD4  29    1     33    34    41    40
            30-         CQUAD4  30    1     34    35    42    41
            31-         CQUAD4  31    1     36    37    44    43
```

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        32-        CQUAD4  32      1       37      38      45      44
        33-        CQUAD4  33      1       38      39      46      45
        34-        CQUAD4  34      1       39      40      47      46
1     RECTANGULAR PLATE - SIMPLY SUPPORTED AR=5  N=6                 APRIL  13, 1988    RELEASE  1987  CDC    PAGE     4

                                          S O R T E D   B U L K   D A T A   E C H O
      CARD
      COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
        35-        CQUAD4  35      1       40      41      48      47
        36-        CQUAD4  36      1       41      42      49      48
        37-        FORCE   2       49              -1.0E-04.0      .0      1.0
        38-        GRID    1               .0000   .0000   .0000
        39-        GRID    2               .0000   .1667   .0000
        40-        GRID    3               .0000   .3333   .0000
        41-        GRID    4               .0000   .5000   .0000
        42-        GRID    5               .0000   .6667   .0000
        43-        GRID    6               .0000   .8333   .0000
        44-        GRID    7               .0000   1.0000  .0000
        45-        GRID    8               .8333   .0000   .0000
        46-        GRID    9               .8333   .1667   .0000
        47-        GRID    10              .8333   .3333   .0000
        48-        GRID    11              .8333   .5000   .0000
        49-        GRID    12              .8333   .6667   .0000
        50-        GRID    13              .8333   .8333   .0000
        51-        GRID    14              .8333   1.0000  .0000
        52-        GRID    15              1.6667  .0000   .0000
        53-        GRID    16              1.6667  .1667   .0000
        54-        GRID    17              1.6667  .3333   .0000
        55-        GRID    18              1.6667  .5000   .0000
        56-        GRID    19              1.6667  .6667   .0000
        57-        GRID    20              1.6667  .8333   .0000
        58-        GRID    21              1.6667  1.0000  .0000
        59-        GRID    22              2.5000  .0000   .0000
        60-        GRID    23              2.5000  .1667   .0000
        61-        GRID    24              2.5000  .3333   .0000
        62-        GRID    25              2.5000  .5000   .0000
        63-        GRID    26              2.5000  .6667   .0000
        64-        GRID    27              2.5000  .8333   .0000
        65-        GRID    28              2.5000  1.0000  .0000
        66-        GRID    29              3.3333  .0000   .0000
        67-        GRID    30              3.3333  .1667   .0000
        68-        GRID    31              3.3333  .3333   .0000
1     RECTANGULAR PLATE - SIMPLY SUPPORTED AR=5  N=6                 APRIL  13, 1988    RELEASE  1987  CDC    PAGE     5

                                          S O R T E D   B U L K   D A T A   E C H O
      CARD
      COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
        69-        GRID    32              3.3333  .5000   .0000
        70-        GRID    33              3.3333  .6667   .0000
        71-        GRID    34              3.3333  .8333   .0000
        72-        GRID    35              3.3333  1.0000  .0000
        73-        GRID    36              4.1667  .0000   .0000
        74-        GRID    37              4.1667  .1667   .0000
        75-        GRID    38              4.1667  .3333   .0000
        76-        GRID    39              4.1667  .5000   .0000
        77-        GRID    40              4.1667  .6667   .0000
        78-        GRID    41              4.1667  .8333   .0000
        79-        GRID    42              4.1667  1.0000  .0000
        80-        GRID    43              5.0000  .0000   .0000
        81-        GRID    44              5.0000  .1667   .0000
        82-        GRID    45              5.0000  .3333   .0000
```

```
83-     GRID    46              5.0000  .5000   .0000
84-     GRID    47              5.0000  .6667   .0000
85-     GRID    48              5.0000  .8333   .0000
86-     GRID    49              5.0000  1.0000  .0000
87-     MAT1    1       1.7472E7        .3
88-     PLOAD2  1       1.0E-0  1       THRU    36
89-     PSHELL  1       1       .001    1       1.0     1       1.0     .0
90-     SPC1    5       6       9       THRU    14
91-     SPC1    5       6       16      THRU    21
92-     SPC1    5       6       23      THRU    28
93-     SPC1    5       6       30      THRU    35
94-     SPC1    5       6       37      THRU    42
95-     SPC1    5       6       44      THRU    49
96-     SPC1    5       15      44      45      46      47      48      49
97-     SPC1    5       24      14      21      28      35      42      49
98-     SPC1    5       1236    1       2       3       4       5       6
99-     SPC1    5       1234    7       8       15      22      29      36
100-    SPC1    5       1236    43
        ENDDATA
```

ID NASTRAN,TISCHLER
APP DISP
SOL 1,0
TIME 500
CEND

PROBLEM #8

SCORDELIS - LO ROOF N = 8 MAY 12, 1988 RELEASE 1987 CDC PAGE 2

C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
  1      TITLE = SCORDELIS - LO ROOF  N = 8
  2      DISP = ALL
  3      STRESS = ALL
  4      OLOAD = ALL
  5      SPCFORCES = ALL
  6      SPC = 8
  7      SUBCASE 1
  8         LOAD = 1
  9      BEGIN BULK
```

0120 USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED. XSORT WILL RE-ORDER DECK.

SCORDELIS - LO ROOF N = 8 MAY 12, 1988 RELEASE 1987 CDC PAGE 3

S O R T E D   B U L K   D A T A   E C H O

```
CARD
COUNT      . 1 .. 2 .. 3 .. 4 .. 5 .. 6 .. 7 .. 8 .. 9 .. 10 .
   1-      CQUAD4  1       1       1       2       11      10
   2-      CQUAD4  2       1       2       3       12      11
   3-      CQUAD4  3       1       3       4       13      12
   4-      CQUAD4  4       1       4       5       14      13
   5-      CQUAD4  5       1       5       6       15      14
   6-      CQUAD4  6       1       6       7       16      15
   7-      CQUAD4  7       1       7       8       17      16
   8-      CQUAD4  8       1       8       9       18      17
   9-      CQUAD4  9       1       10      11      20      19
  10-      CQUAD4  10      1       11      12      21      20
  11-      CQUAD4  11      1       12      13      22      21
  12-      CQUAD4  12      1       13      14      23      22
  13-      CQUAD4  13      1       14      15      24      23
  14-      CQUAD4  14      1       15      16      25      24
  15-      CQUAD4  15      1       16      17      26      25
  16-      CQUAD4  16      1       17      18      27      26
  17-      CQUAD4  17      1       19      20      29      28
  18-      CQUAD4  18      1       20      21      30      29
  19-      CQUAD4  19      1       21      22      31      30
  20-      CQUAD4  20      1       22      23      32      31
  21-      CQUAD4  21      1       23      24      33      32
  22-      CQUAD4  22      1       24      25      34      33
  23-      CQUAD4  23      1       25      26      35      34
  24-      CQUAD4  24      1       26      27      36      35
  25-      CQUAD4  25      1       28      29      38      37
  26-      CQUAD4  26      1       29      30      39      38
  27-      CQUAD4  27      1       30      31      40      39
  28-      CQUAD4  28      1       31      32      41      40
  29-      CQUAD4  29      1       32      33      42      41
  30-      CQUAD4  30      1       33      34      43      42
  31-      CQUAD4  31      1       34      35      44      43
  32-      CQUAD4  32      1       35      36      45      44
  33-      CQUAD4  33      1       37      38      47      46
  34-      CQUAD4  34      1       38      39      48      47
```

```
            85-       GRID    20              14.3394 6.2500  20.4788
            86-       GRID    21              12.5000 6.2500  21.6506
            87-       GRID    22              10.5655 6.2500  22.6577
            88-       GRID    23              8.5505  6.2500  23.4923
            89-       GRID    24              6.4705  6.2500  24.1481
            90-       GRID    25              4.3412  6.2500  24.6202
            91-       GRID    26              2.1789  6.2500  24.9049
            92-       GRID    27              -.0000  6.2500  25.0000
            93-       GRID    28              16.0697 9.3750  19.1511
            94-       GRID    29              14.3394 9.3750  20.4788
            95-       GRID    30              12.5000 9.3750  21.6506
            96-       GRID    31              10.5655 9.3750  22.6577
            97-       GRID    32              8.5505  9.3750  23.4923
            98-       GRID    33              6.4705  9.3750  24.1481
            99-       GRID    34              4.3412  9.3750  24.6202
           100-       GRID    35              2.1789  9.3750  24.9049
           101-       GRID    36              -.0000  9.3750  25.0000
           102-       GRID    37              16.0697 12.5000 19.1511
1     SCORDELIS - LO ROOF  N = 8                                         MAY  12, 1988    RELEASE  1987  CDC    PAGE     6
```

```
0
0                                        S O R T E D   B U L K   D A T A   E C H O
          CARD
          COUNT     .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
           103-       GRID    38              14.3394 12.5000 20.4788
           104-       GRID    39              12.5000 12.5000 21.6506
           105-       GRID    40              10.5655 12.5000 22.6577
           106-       GRID    41              8.5505  12.5000 23.4923
           107-       GRID    42              6.4705  12.5000 24.1481
           108-       GRID    43              4.3412  12.5000 24.6202
           109-       GRID    44              2.1789  12.5000 24.9049
           110-       GRID    45              -.0000  12.5000 25.0000
           111-       GRID    46              16.0697 15.6250 19.1511
           112-       GRID    47              14.3394 15.6250 20.4788
           113-       GRID    48              12.5000 15.6250 21.6506
           114-       GRID    49              10.5655 15.6250 22.6577
           115-       GRID    50              8.5505  15.6250 23.4923
           116-       GRID    51              6.4705  15.6250 24.1481
           117-       GRID    52              4.3412  15.6250 24.6202
           118-       GRID    53              2.1789  15.6250 24.9049
           119-       GRID    54              -.0000  15.6250 25.0000
           120-       GRID    55              16.0697 18.7500 19.1511
           121-       GRID    56              14.3394 18.7500 20.4788
           122-       GRID    57              12.5000 18.7500 21.6506
           123-       GRID    58              10.5655 18.7500 22.6577
           124-       GRID    59              8.5505  18.7500 23.4923
           125-       GRID    60              6.4705  18.7500 24.1481
           126-       GRID    61              4.3412  18.7500 24.6202
           127-       GRID    62              2.1789  18.7500 24.9049
           128-       GRID    63              -.0000  18.7500 25.0000
           129-       GRID    64              16.0697 21.8750 19.1511
           130-       GRID    65              14.3394 21.8750 20.4788
           131-       GRID    66              12.5000 21.8750 21.6506
           132-       GRID    67              10.5655 21.8750 22.6577
           133-       GRID    68              8.5505  21.8750 23.4923
           134-       GRID    69              6.4705  21.8750 24.1481
           135-       GRID    70              4.3412  21.8750 24.6202
           136-       GRID    71              2.1789  21.8750 24.9049
1     SCORDELIS - LO ROOF  N = 8                                         MAY  12, 1988    RELEASE  1987  CDC    PAGE     7
0
0                                        S O R T E D   B U L K   D A T A   E C H O
??
```

```
   85-        GRID    20          14.3394 6.2500  20.4788
   86-        GRID    21          12.5000 6.2500  21.0506
   87-        GRID    22          10.5655 6.2500  22.0577
   88-        GRID    23          8.5505  6.2500  23.4923
   89-        GRID    24          6.4705  6.2500  24.1481
   90-        GRID    25          4.3412  6.2500  24.6202
   91-        GRID    26          2.1789  6.2500  24.9049
   92-        GRID    27          -.0000  6.2500  25.0000
   93-        GRID    28          18.8687 9.3750  19.1511
   94-        GRID    29          14.3394 9.3750  20.4788
   95-        GRID    30          12.5000 9.3750  21.0506
   96-        GRID    31          10.5655 9.3750  22.0577
   97-        GRID    32          8.5505  9.3750  23.4923
   98-        GRID    33          6.4705  9.3750  24.1481
   99-        GRID    34          4.3412  9.3750  24.6202
  100-        GRID    35          2.1789  9.3750  24.9049
  101-        GRID    36          -.0000  9.3750  25.0000
  102-        GRID    37          18.8687 12.5000 19.1511
1   SCORDELIS - LO ROOF  N = 8                              MAY 18, 1988   RELEASE 1987 CDC    PAGE    6
0
0                                 S O R T E D   B U L K   D A T A   E C H O
     CARD
     COUNT        .   1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
  103-        GRID    38          14.3394 12.5000 20.4788
  104-        GRID    39          12.5000 12.5000 21.0506
  105-        GRID    40          10.5655 12.5000 22.0577
  106-        GRID    41          8.5505  12.5000 23.4923
  107-        GRID    42          6.4705  12.5000 24.1481
  108-        GRID    43          4.3412  12.5000 24.6202
  109-        GRID    44          2.1789  12.5000 24.9049
  110-        GRID    45          -.0000  12.5000 25.0000
  111-        GRID    46          18.8687 15.6250 19.1511
  112-        GRID    47          14.3394 15.6250 20.4788
  113-        GRID    48          12.5000 15.6250 21.0506
  114-        GRID    49          10.5655 15.6250 22.0577
  115-        GRID    50          8.5505  15.6250 23.4923
  116-        GRID    51          6.4705  15.6250 24.1481
  117-        GRID    52          4.3412  15.6250 24.6202
  118-        GRID    53          2.1789  15.6250 24.9049
  119-        GRID    54          -.0000  15.6250 25.0000
  120-        GRID    55          18.8687 18.7500 19.1511
  121-        GRID    56          14.3394 18.7500 20.4788
  122-        GRID    57          12.5000 18.7500 21.0506
  123-        GRID    58          10.5655 18.7500 22.0577
  124-        GRID    59          8.5505  18.7500 23.4923
  125-        GRID    60          6.4705  18.7500 24.1481
  126-        GRID    61          4.3412  18.7500 24.6202
  127-        GRID    62          2.1789  18.7500 24.9049
  128-        GRID    63          -.0000  18.7500 25.0000
  129-        GRID    64          18.8687 21.8750 19.1511
  130-        GRID    65          14.3394 21.8750 20.4788
  131-        GRID    66          12.5000 21.8750 21.0506
  132-        GRID    67          10.5655 21.8750 22.0577
  133-        GRID    68          8.5505  21.8750 23.4923
  134-        GRID    69          6.4705  21.8750 24.1481
  135-        GRID    70          4.3412  21.8750 24.6202
  136-        GRID    71          2.1789  21.8750 24.9049
1   SCORDELIS - LO ROOF  N = 8                              MAY 18, 1988   RELEASE 1987 CDC    PAGE    7
0
0                                 S O R T E D   B U L K   D A T A   E C H O
```

CARD COUNT	1	2	3	4	5	6	7	8	9	10
137-	GRID	72		.0000	21.8750	25.0000				
138-	GRID	73		16.0697	25.0000	19.1511				
139-	GRID	74		14.3394	25.0000	20.4788				
140-	GRID	75		12.5000	25.0000	21.6506				
141-	GRID	76		10.5655	25.0000	22.6577				
142-	GRID	77		8.5505	25.0000	23.4923				
143-	GRID	78		6.4705	25.0000	24.1481				
144-	GRID	79		4.3412	25.0000	24.6202				
145-	GRID	80		2.1780	25.0000	24.9049				
146-	GRID	81		-.0000	25.0000	25.0000				
147-	MAT1	1	4.32 E08		.0	11.18012				
148-	PSHELL	1	1	.25	1	1.0	1	1.0	.0	
149-	SPC1	5	6	1	THRU	81				
150-	SPC1	5	13	1	2	3	4	5	6	+BCD
151-	+BCD	7	8	9						
152-	SPC1	5	15	9	18	27	36	45	54	+CDE
153-	+CDE	63	72	81						
154-	SPC1	5	24	73	74	75	76	77	78	+ABC
155-	+ABC	79	80	81						
	ENDDATA									

```
ID UAI,NASTRAN PROBLEM 1
SOL 1,0
APP DISP
TIME 30
CEND
1    LAMINATED COMPOSITE PLATE                                          MARCH  22, 1989   RELEASE  1988  CDC    PAGE    2
     PURE TWIST LOADING
0
0                                       C A S E    C O N T R O L    D E C K   E C H O
                 CARD
                 COUNT
                  1      TITLE = LAMINATED COMPOSITE PLATE
                  2      SUBTITLE = PURE TWIST LOADING
                  3      $
                  4      $  MODEL: A SQUARE PLATE OF A 4X4 MESH WITH THREE CORNERS
                  5      $         PINNED AND A TRANSVERSE POINT LOAD AT THE FREE
                  6      $         CORNER TO SIMULATE A PURE TWIST LOADING.  THE
                  7      $         LAMINATE LAYUP IS OF A CROSS-PLY CONFIGURATION
                  8      $         [0/90/0].
                  9      $
                 10      $      * * COMPARISON OF T3 DEFLECTION AT GRID 1 * *
                 11      $
                 12      $       UAI/NASTRAN      MSC/NASTRAN       THEORETICAL
                 13      $      ---------------------------------------------------
                 14      $       -3.756E-2        -3.763E-2         -3.750E-2
                 15      $
                 16      $
                 17      $      * * COMPARISON OF TAU FOR ELEMENT 1, ALL LAYERS * *
                 18      $
                 19      $       UAI/NASTRAN      MSC/NASTRAN       THEORETICAL
                 20      $      ---------------------------------------------------
                 21      $ PLY 1  -5.0E1           -5.0E1           -5.0E1
                 22      $ PLY 2   0.0              0.0               0.0
                 23      $ PLY 3   5.0E1            5.0E1            5.0E1
                 24      $
                 25      $
                 26      $
                 27      $  REFERENCES:  JONES R. M., MECHANICS OF COMPOSITE MATERIALS.
                 28      $               M GRAW-HILL BOOK COMPANY.  (PAGE 181)
                 29      $
                 30      $
                 31      $
                 32      SPC = 1
                 33      SUBCASE 1
                 34      LABEL = LAYER STRESS REQUEST
1    LAMINATED COMPOSITE PLATE                                          MARCH  22, 1989   RELEASE  1988  CDC    PAGE    3
     PURE TWIST LOADING
0
0                                       C A S E    C O N T R O L    D E C K   E C H O
                 CARD
                 COUNT
                 35      DISP = ALL
                 36      STRESS(LAYER) = ALL
                 37      FORCE = ALL
                 38      LOAD = 1
                 39      BEGIN BULK
1    LAMINATED COMPOSITE PLATE                                          MARCH  22, 1989   RELEASE  1988  CDC    PAGE    4
     PURE TWIST LOADING
0
0
0
0*** USER INFORMATION MESSAGE 207,  BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1    LAMINATED COMPOSITE PLATE                                          MARCH  22, 1989   RELEASE  1988  CDC    PAGE    5
```

PURE TWIST LOADING

S O R T E D   B U L K   D A T A   E C H O

```
CARD
COUNT    ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
   1-    CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +CDE
   2-    +CDE    1.0     0.0     1.0
   3-    CQUAD4  1       3       1       2       5       4       1
   4-    CQUAD4  2       3       2       3       6       5       1
   5-    CQUAD4  3       3       4       5       8       7       1
   6-    CQUAD4  4       3       5       6       9       8       1
   7-    FORCE   1       1               1.0     0.0     0.0     -1.0
   8-    GRID    1               0.0     0.0
   9-    GRID    2               2.5     0.0
  10-    GRID    3               5.0     0.0
  11-    GRID    4               0.0     2.5
  12-    GRID    5               2.5     2.5
  13-    GRID    6               5.0     2.5
  14-    GRID    7               0.0     5.0
  15-    GRID    8               2.5     5.0
  16-    GRID    9               5.0     5.0
  17-    MAT8    3       2.0  E+75.0  E+5.25     25.0E+04                        +ABC
  18-    +ABC                            1.6 E+051.2 E+042.0 E+053.0 E+041.5 E+04
  19-    PARAM   PLYDATA PRINT
  20-    PCOMP1  3                       1.2 E+04HILL    3       .0666566        +BCD
  21-    +BCD    0.0     90.0    0.0
  22-    SPC1    1       6       1       2       4       5       6       8
  23-    SPC1    1       1236    3       7       9
         ENDDATA
```

```
ID UAI,NASTRAN PROBLEM 9
TIME 1.0
APP DISP
SOL 24
CEND
```

COMP61 *** UAI *** QUAD4 FLAT PLATE TEST   MARCH 22, 1989   RELEASE 1988 CDC   PAGE 2

MESH 4X4 , ASPECT RATIO 1.0 SYMM CROSS-PLY [0/90/0]

C A S E   C O N T R O L   D E C K   E C H O

```
CARD
COUNT
 1      TITLE = COMP61 *** UAI *** QUAD4 FLAT PLATE TEST
 2      LABEL = MESH 4X4 , ASPECT RATIO 1.0 SYMM CROSS-PLY [0/90/0]
 3      $
 4      $    MODEL: = QUARTER MODEL OF A SIMPLY SUPPORTED FLAT PLATE
 5      $             IN A SYMMETRIC CROSS-PLY CONFIGURATION [0/90/0]
 6      $             UNDER A UNIFORM PRESSURE LOADING.
 7      $
 8      $      * * COMPARISON OF T3 DEFLECTION AT GRID 25 * *
 9      $
10      $        UAI/NASTRAN      MSC/NASTRAN       THEORETICAL
11      $        ----------------------------------------------
12      $        -1.852E-3        -1.739E-3         -1.8??E-3
13      $
14      $
15      $
16      $    REFERENCE: JONES,R.M. , MECHANICS OF COMPOSITE MATERIALS,
17      $               MC GRAW-HILL BOOK COMPANY.  (PAGE 248-250)
18      $
19      $
20      SET 1 = 2,7,12,17
21      DISP = ALL
22      STRESS(LAYER) = 1
23      FORCE = 1
24      SUBCASE 1
25          SUBTITLE = SIMPLE SUPPORTS, UNIFORM LOAD
26          SPC = 1
27          LOAD = 1
28      BEGIN BULK
```

COMP61 *** UAI *** QUAD4 FLAT PLATE TEST   MARCH 22, 1989   RELEASE 1988 CDC   PAGE 3

MESH 4X4 , ASPECT RATIO 1.0 SYMM CROSS-PLY [0/90/0]

*** USER INFORMATION MESSAGE 207, BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.

COMP61 *** UAI *** QUAD4 FLAT PLATE TEST   MARCH 22, 1989   RELEASE 1988 CDC   PAGE 4

MESH 4X4 , ASPECT RATIO 1.0 SYMM CROSS-PLY [0/90/0]

S O R T E D   B U L K   D A T A   E C H O

```
CARD
COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
  1-         CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +ABC
  2-         +ABC    1.0     0.0     1.0
  3-         CQUAD4  2       1       1       6       7       2       1
  4-         CQUAD4  3       1       6       11      12      7       1
  5-         CQUAD4  4       1       11      16      17      12      1
  6-         CQUAD4  5       1       16      21      22      17      1
  7-         CQUAD4  6       1       2       7       8       3       1
  8-         CQUAD4  7       1       7       12      13      8       1
  9-         CQUAD4  8       1       12      17      18      13      1
 10-         CQUAD4  9       1       17      22      23      18      1
 11-         CQUAD4  10      1       3       8       9       4       1
 12-         CQUAD4  11      1       8       13      14      9       1
```

```
      13-        CQUAD4  12      1       13      18      19      14      1
      14-        CQUAD4  13      1       18      23      24      19      1
      15-        CQUAD4  14      1       4       9       10      5       1
      16-        CQUAD4  15      1       9       14      15      10      1
      17-        CQUAD4  16      1       14      19      20      15      1
      18-        CQUAD4  17      1       19      24      25      20      1
      19-        GRID    1               0.000   0.000   0.000
      20-        GRID    2               0.000   .250    0.000
      21-        GRID    3               0.000   .500    0.000
      22-        GRID    4               0.000   .750    0.000
      23-        GRID    5               0.000   1.000   0.000
      24-        GRID    6               .250    0.000   0.000
      25-        GRID    7               .250    .250    0.000
      26-        GRID    8               .250    .500    0.000
      27-        GRID    9               .250    .750    0.000
      28-        GRID    10              .250    1.000   0.000
      29-        GRID    11              .500    0.000   0.000
      30-        GRID    12              .500    .250    0.000
      31-        GRID    13              .500    .500    0.000
      32-        GRID    14              .500    .750    0.000
      33-        GRID    15              .500    1.000   0.000
      34-        GRID    16              .750    0.000   0.000
1   COMP01 *** UAI *** QUAD4 FLAT PLATE TEST                        MARCH  22, 1989    RELEASE  1988  CDC    PAGE     5

0   MESH 4X4 , ASPECT RATIO 1.0 SYMM CROSS-PLY [0/90/0]
0                                         S O R T E D   B U L K   D A T A   E C H O
     CARD
     COUNT       ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
      35-        GRID    17              .750    .250    0.000
      36-        GRID    18              .750    .500    0.000
      37-        GRID    19              .750    .750    0.000
      38-        GRID    20              .750    1.000   0.000
      39-        GRID    21              1.000   0.000   0.000
      40-        GRID    22              1.000   .250    0.000
      41-        GRID    23              1.000   .500    0.000
      42-        GRID    24              1.000   .750    0.000
      43-        GRID    25              1.000   1.000   0.000
      44-        MAT8    1       20.0E+06.50   E+6.25    .250 E+6
      45-        PCOMP   1       -.001                                           +PC1
      46-        +PC1    1       .000666 0.0     YES     1       .000666 90.0    YES     +PC2
      47-        +PC2    1       .000666 0.0     YES
      48-        PLOAD4  1       2       -1.0E-04                        THRU    17
      49-        SPC1    1       6       1       THRU    25
      50-        SPC1    1       15      22      23      24
      51-        SPC1    1       24      10      15      20
      52-        SPC1    1       1234    2       3       4       5
      53-        SPC1    1       1235    6       11      16      21
      54-        SPC1    1       1245    25
      55-        SPC1    1       12345   1
                 ENDDATA
```

```
     ID UAI,NASTRAN PROBLEM 4
     SOL 1,0
     APP DISP
     TIME 30
     CEND
1     COMP04 *** UAI *** QUAD4 4-NODE STRAIGHT BEAM TEST                MARCH  22, 1989    RELEASE  1988  CDC    PAGE     2

0     REGULAR SHAPE ELEMENTS ( ISOTROPIC PROPERTIES)
0                              C A S E    C O N T R O L   D E C K   E C H O
              CARD
              COUNT
               1      TITLE = COMP04 *** UAI *** QUAD4 4-NODE STRAIGHT BEAM TEST
               2      LABEL = REGULAR SHAPE ELEMENTS ( ISOTROPIC PROPERTIES)
               3      $
               4      $    MODEL: CANTILEVERED BEAM MODEL UNDER A) EXTENSIONAL AND
               5      $           B) BENDING LOADINGS.  SIMULATION OF EQUIVALENT
               6      $           ISOTROPIC PROPERTIES. LAMINATE CONFIGURATION
               7      $           [0/0/0/0]
               8      $
               9      $      * * COMPARISON OF T1 DEFLECTION AT GRIDS 13 AND 14 * *
              10      $
              11      $           UAI/NASTRAN      MSC/NASTRAN       THEORETICAL
              12      $        ------------------------------------------------
              13      $ SUBCASE 1 (EXTENSIONAL)
              14      $
              15      $ GRID 13   2.986E-5          2.986E-5           3.0E-5
              16      $ GRID 14   2.986E-5          2.986E-5           3.0E-5
              17      $
              18      $      * * COMPARISON OF T3 DEFLECTION AT GRIDS 13 AND 14 * *
              19      $
              20      $           UAI/NASTRAN      MSC/NASTRAN       THEORETICAL
              21      $        ------------------------------------------------
              22      $ SUBCASE 2 (BENDING)
              23      $
              24      $ GRID 13   4.253E-1          4.253E-1           4.320E-1
              25      $ GRID 14   4.253E-1          4.253E-1           4.320E-1
              26      $
              27      $
              28      $       * * COMPARISON OF BENDING MOMENT DISTRIBUTION FROM * *
              29      $       * * THE FREE END TO THE CANTILEVERED END           * *
              30      $           NOTE: THE BENDING MOMENTS ARE AT THE ELEMENT CENTER
              31      $
              32      $            UAI/NASTRAN      MSC/NASTRAN       THEORETICAL
              33      $        --------------------------------------------------
              34      $          2.500E0           2.500E0           2.500E0
1     COMP04 *** UAI *** QUAD4 4-NODE STRAIGHT BEAM TEST                MARCH  22, 1989    RELEASE  1988  CDC    PAGE     3

0     REGULAR SHAPE ELEMENTS ( ISOTROPIC PROPERTIES)
0                              C A S E    C O N T R O L   D E C K   E C H O
              CARD
              COUNT
              35      $          7.500E0           7.500E0           7.500E0
              36      $          1.250E1           1.250E1           1.250E1
              37      $          1.750E1           1.750E1           1.750E1
              38      $          2.250E1           2.250E1           2.250E1
              39      $          2.750E1           2.750E1           2.750E1
              40      $
              41      $
              42      $       * * COMPARISON OF DIRECT LAYER BENDING STRESS * *
              43      $       * * ELEMENT 6 (LARGEST BENDING MOMENT)        * *
              44      $
              45      $            UAI/NASTRAN      MSC/NASTRAN
              46      $        -------------------------------------
```

```
                  46      $         ---------------------------------------
                  47      $
                  48      $  LAYER 1   1.238E4             1.238E4
                  49      $  LAYER 2   4.125E3             4.126E3
                  50      $  LAYER 3  -4.125E3            -4.126E3
                  51      $  LAYER 4  -1.238E4            -1.238E4
                  52      $
                  53      $
                  54      $
                  55      STRESS(LAYER) = ALL
                  56      DISP = ALL
                  57      FORCE = ALL
                  58      SPC = 1
                  59      SUBCASE 1
                  60         SUBTITLE = EXTENSION
                  61         LOAD = 1
                  62      SUBCASE 2
                  63         SUBTITLE = OUT-OF-PLANE SHEAR
                  64         LOAD = 2
                  65      BEGIN BULK
1     COMP04 *** UAI *** QUAD4 4-NODE STRAIGHT BEAM TEST                     MARCH  22, 1989    RELEASE  1988  CDC    PAGE     4

0
0
0*** USER INFORMATION MESSAGE 207,  BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
1     COMP04 *** UAI *** QUAD4 4-NODE STRAIGHT BEAM TEST                     MARCH  22, 1989    RELEASE  1988  CDC    PAGE     5

0     REGULAR SHAPE ELEMENTS ( ISOTROPIC PROPERTIES)
0                                                  S O R T E D   B U L K   D A T A   E C H O
                  CARD
                  COUNT      ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
                     1-      CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +ABC
                     2-      +ABC    1.0     0.0     1.0
                     3-      CQUAD4  1       1       3       5       6       4       1
                     4-      CQUAD4  2       1       5       7       8       6       1
                     5-      CQUAD4  3       1       7       9       10      8       1
                     6-      CQUAD4  4       1       9       11      12      10      1
                     7-      CQUAD4  5       1       11      13      14      12      1
                     8-      CQUAD4  6       1       1       3       4       2       1
                     9-      FORCE   [illegible] 13              0.5     1.0     0.0     0.0
                    10-      FORCE   [illegible] 14              0.5     1.0     0.0     0.0
                    11-      FORCE   [illegible] 13              0.5     0.0     0.0     1.0
                    12-      FORCE   [illegible] 14              0.5     0.0     0.0     1.0
                    13-      GRID    1               0.0     0.0     0.0
                    14-      GRID    2               0.0     0.200   0.0
                    15-      GRID    3               1.0     0.0     0.0
                    16-      GRID    4               1.0     0.2     0.0
                    17-      GRID    5               2.0     0.0     0.0
                    18-      GRID    6               2.0     0.2     0.0
                    19-      GRID    7               3.0     0.0     0.0
                    20-      GRID    8               3.0     0.2     0.0
                    21-      GRID    9               4.0     0.0     0.0
                    22-      GRID    10              4.0     0.2     0.0
                    23-      GRID    11              5.0     0.0     0.0
                    24-      GRID    12              5.0     0.2     0.0
                    25-      GRID    13              6.0     0.0     0.0
                    26-      GRID    14              6.0     0.2     0.0
                    27-      MAT1    1       .100E+08        0.300
                    28-      PCOMP2  1                                       1                       SYM     +PC1
                    29-      +PC1    0.025   0.0     0.025   0.0
                    30-      SPC1    1       6       1       THRU    14
                    31-      SPC1    1       123456  1       2
                             ENDDATA
```

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 1,0
TIME 10
CEND

                 C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      TITLE = PROBLEM 13 CASE 3 COMBINED LOADING
  2      LOAD = 1
  3      SPC  = 1
  4      OUTPUT
  5         OLOAD=ALL
  6         STRESS=ALL
  7         DISPLACEMENTS=ALL
  8         STRAIN=ALL
  9      BEGIN BULK

                   S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
   1-        CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
   2-        +XYP    1.0     0.0     1.0
   3-        CQUAD4  1       1       1       2       8       7       1
   4-        CQUAD4  2       1       2       3       9       8       1
   5-        CQUAD4  3       1       3       4       10      9       1
   6-        CQUAD4  4       1       4       5       11      10      1
   7-        CQUAD4  5       1       5       6       12      11      1
   8-        CQUAD4  6       1       7       8       14      13      1
   9-        CQUAD4  7       1       8       9       15      14      1
  10-        CQUAD4  8       1       9       10      16      15      1
  11-        CQUAD4  9       1       10      11      17      16      1
  12-        CQUAD4  10      1       11      12      18      17      1
  13-        CQUAD4  11      1       13      14      20      19      1
  14-        CQUAD4  12      1       14      15      21      20      1
  15-        CQUAD4  13      1       15      16      22      21      1
  16-        CQUAD4  14      1       16      17      23      22      1
  17-        CQUAD4  15      1       17      18      24      23      1
  18-        CQUAD4  16      1       19      20      25      25      1
  19-        CQUAD4  17      1       20      21      27      26      1
  20-        CQUAD4  18      1       21      22      28      27      1
  21-        CQUAD4  19      1       22      23      29      28      1
  22-        CQUAD4  20      1       23      24      30      29      1
  23-        CQUAD4  21      1       25      26      32      31      1
  24-        CQUAD4  22      1       26      27      33      32      1
  25-        CQUAD4  23      1       27      28      34      33      1
  26-        CQUAD4  24      1       28      29      35      34      1
  27-        CQUAD4  25      1       29      30      36      35      1
```

```
28-    FORCE   1       5               -2.0    1.0     0.0     0.0
29-    FORCE   1       12              -4.0    1.0     0.0     0.0
30-    FORCE   1       18              -4.0    1.0     0.0     0.0
31-    FORCE   1       24              -4.0    1.0     0.0     0.0
32-    FORCE   1       30              -4.0    1.0     0.0     0.0
33-    FORCE   1       36              -2.0    1.0     0.0     0.0
34-    GRID    1               0.0     0.0     0.0
35-    GRID    2               3.0     0.0     0.0
36-    GRID    3               6.0     0.0     0.0
37-    GRID    4               9.0     0.0     0.0
38-    GRID    5               12.0    0.0     0.0
39-    GRID    6               15.0    0.0     0.0
40-    GRID    7               0.0     4.0     0.0
41-    GRID    8               3.0     4.0     0.0
42-    GRID    9               6.0     4.0     0.0
43-    GRID    10              9.0     4.0     0.0
44-    GRID    11              12.0    4.0     0.0
45-    GRID    12              15.0    4.0     0.0
46-    GRID    13              0.0     8.0     0.0
47-    GRID    14              3.0     8.0     0.0
48-    GRID    15              6.0     8.0     0.0
49-    GRID    16              9.0     8.0     0.0
50-    GRID    17              12.0    8.0     0.0
51-    GRID    18              15.0    8.0     0.0
52-    GRID    19              0.0     12.0    0.0
53-    GRID    20              3.0     12.0    0.0
54-    GRID    21              6.0     12.0    0.0
55-    GRID    22              9.0     12.0    0.0
56-    GRID    23              12.0    12.0    0.0
57-    GRID    24              15.0    12.0    0.0
58-    GRID    25              0.0     16.0    0.0
59-    GRID    26              3.0     16.0    0.0
60-    GRID    27              6.0     16.0    0.0
61-    GRID    28              [illegible]  16.0    0.0
62-    GRID    29              12.0    16.0    0.0
63-    GRID    30              15.0    16.0    0.0
64-    GRID    31              0.0     20.0    0.0
65-    GRID    32              3.0     20.0    0.0
66-    GRID    33              6.0     20.0    0.0
67-    GRID    34              9.0     20.0    0.0
68-    GRID    35              12.0    20.0    0.0
69-    GRID    36              15.0    20.0    0.0
70-    MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
71-    PARAM   GRDPNT  0
72-    PCOMP1  1                                       22      .0236   SYM     ABC
73-    +BC     45.     -45.    90.     0.
74-    PLOAD2  1       -2.0    1       THRU    25
75-    SPC1    1       6       1       THRU    36
76-    SPC1    1       36      1       THRU    6
77-    SPC1    1       35      6       12      18      24      30      36
78-    SPC1    1       136     1       7       13      19      25      31
79-    SPC1    1       235     31      THRU    36
       ENDDATA
```

APPENDIX E: NASTRAN INPUT AND OUTPUT FOR SAMPLE PROBLEMS 7, 10, 12, 13a, 13b, 13d, 14, and 9 and 12 with TRIA3

N A S T R A N E X E C U T I V E C O N T R O L D E C K E C H O

PROBLEM 47

```
ID NASTRAN,FISCHLER
APP DISP
SOL 1,0
TIME 5
CEND
```

```
                         C A S E   C O N T R O L   D E C K   E C H O
     CARD
     COUNT
       1      TITLE = SPHERICAL SHELL  -  N=8
       2      DISP = ALL
       3      STRESS = ALL
       4      OLOAD = ALL
       5      SPCFORCES = ALL
       6      SPC = 5
       7      SUBCASE 1
       8         LOAD = 1
       9      BEGIN BULK
```

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
1-	CORD2S	1		.0	.0	.0	.0	.0	1.0	+ABC
2-	+ABC	1.0	0.0	1.0						
3-	CQUAD4	1	1	1	2	11	10			
4-	CQUAD4	2	1	2	3	12	11			
5-	CQUAD4	3	1	3	4	13	12			
6-	CQUAD4	4	1	4	5	14	13			
7-	CQUAD4	5	1	5	6	15	14			
8-	CQUAD4	6	1	6	7	16	15			
9-	CQUAD4	7	1	7	8	17	16			
10-	CQUAD4	8	1	8	9	18	17			
11-	CQUAD4	9	1	10	11	20	19			
12-	CQUAD4	10	1	11	12	21	20			
13-	CQUAD4	11	1	12	13	22	21			
14-	CQUAD4	12	1	13	14	23	22			
15-	CQUAD4	13	1	14	15	24	23			
16-	CQUAD4	14	1	15	16	25	24			
17-	CQUAD4	15	1	16	17	26	25			
18-	CQUAD4	16	1	17	18	27	26			
19-	CQUAD4	17	1	19	20	29	28			
20-	CQUAD4	18	1	20	21	30	29			
21-	CQUAD4	19	1	21	22	31	30			
22-	CQUAD4	20	1	22	23	32	31			
23-	CQUAD4	21	1	23	24	33	32			
24-	CQUAD4	22	1	24	25	34	33			
25-	CQUAD4	23	1	25	26	35	34			
26-	CQUAD4	24	1	26	27	36	35			
27-	CQUAD4	25	1	28	29	38	37			
28-	CQUAD4	26	1	29	30	39	38			
29-	CQUAD4	27	1	30	31	40	39			
30-	CQUAD4	28	1	31	32	41	40			
31-	CQUAD4	29	1	32	33	42	41			
32-	CQUAD4	30	1	33	34	43	42			
33-	CQUAD4	31	1	34	35	44	43			
34-	CQUAD4	32	1	35	36	45	44			

0
0
S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 ..	8 ..	9 ..	10 .
35-	CQUAD4 33	1	37	38	47	46				
36-	CQUAD4 34	1	38	39	48	47				
37-	CQUAD4 35	1	39	40	49	48				
38-	CQUAD4 36	1	40	41	50	49				
39-	CQUAD4 37	1	41	42	51	50				
40-	CQUAD4 38	1	42	43	52	51				
41-	CQUAD4 39	1	43	44	53	52				
42-	CQUAD4 40	1	44	45	54	53				
43-	CQUAD4 41	1	46	47	56	55				
44-	CQUAD4 42	1	47	48	57	56				
45-	CQUAD4 43	1	48	49	58	57				
46-	CQUAD4 44	1	49	50	59	58				
47-	CQUAD4 45	1	50	51	60	59				
48-	CQUAD4 46	1	51	52	61	60				
49-	CQUAD4 47	1	52	53	62	61				
50-	CQUAD4 48	1	53	54	63	62				
51-	CQUAD4 49	1	55	56	65	64				
52-	CQUAD4 50	1	56	57	66	65				
53-	CQUAD4 51	1	57	58	67	66				
54-	CQUAD4 52	1	58	59	68	67				
55-	CQUAD4 53	1	59	60	69	68				
56-	CQUAD4 54	1	60	61	70	69				
57-	CQUAD4 55	1	61	62	71	70				
58-	CQUAD4 56	1	62	63	72	71				
59-	CQUAD4 57	1	64	65	74	73				
60-	CQUAD4 58	1	65	66	75	74				
61-	CQUAD4 59	1	66	67	76	75				
62-	CQUAD4 60	1	67	68	77	76				
63-	CQUAD4 61	1	68	69	78	77				
64-	CQUAD4 62	1	69	70	79	78				
65-	CQUAD4 63	1	70	71	80	79				
66-	CQUAD4 64	1	71	72	81	80				
67-	FORCE 1	1		1.0	1.0	.0	.0			
68-	FORCE 1	73		-1.0	.0	1.0	.0			

??

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 .. 8 .. 9 .. 10 .
69-	GRID	1	1	10.00	90.00	.00	
70-	GRID	2	1	10.00	81.00	.00	
71-	GRID	3	1	10.00	72.00	.00	
72-	GRID	4	1	10.00	63.00	.00	
73-	GRID	5	1	10.00	54.00	.00	
74-	GRID	6	1	10.00	45.00	.00	
75-	GRID	7	1	10.00	36.00	.00	
76-	GRID	8	1	10.00	27.00	.00	
77-	GRID	9	1	10.00	18.00	.00	
78-	GRID	10	1	10.00	90.00	11.25	
79-	GRID	11	1	10.00	81.00	11.25	
80-	GRID	12	1	10.00	72.00	11.25	
81-	GRID	13	1	10.00	63.00	11.25	
82-	GRID	14	1	10.00	54.00	11.25	
83-	GRID	15	1	10.00	45.00	11.25	
84-	GRID	16	1	10.00	36.00	11.25	
85-	GRID	17	1	10.00	27.00	11.25	
86-	GRID	18	1	10.00	18.00	11.25	
87-	GRID	19	1	10.00	90.00	22.50	
88-	GRID	20	1	10.00	81.00	22.50	
89-	GRID	21	1	10.00	72.00	22.50	
90-	GRID	22	1	10.00	63.00	22.50	
91-	GRID	23	1	10.00	54.00	22.50	
92-	GRID	24	1	10.00	45.00	22.50	
93-	GRID	25	1	10.00	36.00	22.50	
94-	GRID	26	1	10.00	27.00	22.50	
95-	GRID	27	1	10.00	18.00	22.50	
96-	GRID	28	1	10.00	90.00	33.75	
97-	GRID	29	1	10.00	81.00	33.75	
98-	GRID	30	1	10.00	72.00	33.75	
99-	GRID	31	1	10.00	63.00	33.75	
100-	GRID	32	1	10.00	54.00	33.75	
101-	GRID	33	1	10.00	45.00	33.75	
102-	GRID	34	1	10.00	36.00	33.75	

SORTED BULK DATA ECHO

CARD COUNT	. 1 ..	2 ..	3 ..	4 ..	5 ..	6 ..	7 .. 8 .. 9 .. 10 .
103-	GRID	35	1	10.00	27.00	33.75	
104-	GRID	36	1	10.00	18.00	33.75	
105-	GRID	37	1	10.00	90.00	45.00	
106-	GRID	38	1	10.00	81.00	45.00	
107-	GRID	39	1	10.00	72.00	45.00	
108-	GRID	40	1	10.00	63.00	45.00	
109-	GRID	41	1	10.00	54.00	45.00	
110-	GRID	42	1	10.00	45.00	45.00	
111-	GRID	43	1	10.00	36.00	45.00	
112-	GRID	44	1	10.00	27.00	45.00	
113-	GRID	45	1	10.00	18.00	45.00	
114-	GRID	46	1	10.00	90.00	56.25	
115-	GRID	47	1	10.00	81.00	56.25	
116-	GRID	48	1	10.00	72.00	56.25	
117-	GRID	49	1	10.00	63.00	56.25	
118-	GRID	50	1	10.00	54.00	56.25	
119-	GRID	51	1	10.00	45.00	56.25	
120-	GRID	52	1	10.00	36.00	56.25	
121-	GRID	53	1	10.00	27.00	56.25	
122-	GRID	54	1	10.00	18.00	56.25	
123-	GRID	55	1	10.00	90.00	67.50	
124-	GRID	56	1	10.00	81.00	67.50	
125-	GRID	57	1	10.00	72.00	67.50	
126-	GRID	58	1	10.00	63.00	67.50	
127-	GRID	59	1	10.00	54.00	67.50	
128-	GRID	60	1	10.00	45.00	67.50	
129-	GRID	61	1	10.00	36.00	67.50	
130-	GRID	62	1	10.00	27.00	67.50	
131-	GRID	63	1	10.00	18.00	67.50	
132-	GRID	64	1	10.00	90.00	78.75	
133-	GRID	65	1	10.00	81.00	78.75	
134-	GRID	66	1	10.00	72.00	78.75	
135-	GRID	67	1	10.00	63.00	78.75	
136-	GRID	68	1	10.00	54.00	78.75	

SORTED BULK DATA ECHO

```
●
●
        CARD
        COUNT      .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
         137-      GRID    69      1             10.00    45.00    78.75
         138-      GRID    70      1             10.00    36.00    78.75
         139-      GRID    71      1             10.00    27.00    78.75
         140-      GRID    72      1             10.00    18.00    78.75
         141-      GRID    73      1             10.00    90.00    90.00
         142-      GRID    74      1             10.00    81.00    90.00
         143-      GRID    75      1             10.00    72.00    90.00
         144-      GRID    76      1             10.00    63.00    90.00
         145-      GRID    77      1             10.00    54.00    90.00
         146-      GRID    78      1             10.00    45.00    90.00
         147-      GRID    79      1             10.00    36.00    90.00
         148-      GRID    80      1             10.00    27.00    90.00
         149-      GRID    81      1             10.00    18.00    90.00
         150-      MAT1    1       6.825E07               .3
         151-      PSHELL  1       1         .04      1        1.0      1        1.0      0.0
         152-      SPC1    5       3         9
         153-      SPC1    5       156       73       74       75       76       77       78       +XYZ
         154-      +XYZ    79      80        81
         155-      SPC1    5       246       1        2        3        4        5        6        +BCD
         156-      +BCD    7       8         9
                   ENDDATA
??
```

0 SUBCASE 1

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	9.544737E-02	.0	4.349715E-02	.0	-1.905434E-02	.0
2	G	6.788819E-02	.0	4.132864E-02	.0	-1.563841E-02	.0
3	G	4.695500E-02	.0	3.630303E-02	.0	-1.204459E-02	.0
4	G	3.123232E-02	.0	2.979120E-02	.0	-9.686679E-03	.0
5	G	1.960743E-02	.0	2.260793E-02	.0	-7.720540E-03	.0
6	G	1.137281E-02	.0	1.563621E-02	.0	-6.100912E-03	.0
7	G	5.892211E-03	.0	9.218681E-03	.0	-4.663406E-03	.0
8	G	2.618190E-03	.0	3.875984E-03	.0	-3.311706E-03	.0
9	G	1.012620E-03	.0	.0	.0	-2.302808E-03	.0
10	G	8.770363E-02	-7.725300E-04	3.949158E-02	1.278609E-06	-1.662371E-02	7.472304E-03
11	G	6.319187E-02	-4.562569E-04	3.760460E-02	-1.690150E-03	-1.448311E-02	4.415313E-03
12	G	4.398692E-02	-2.955313E-04	3.300955E-02	-1.553613E-03	-1.144960E-02	2.913439E-03
13	G	2.935179E-02	-1.843323E-04	2.715206E-02	-1.268340E-03	-9.284242E-03	2.030600E-03
14	G	1.845969E-02	-1.136186E-04	2.061461E-02	-1.216800E-03	-7.483871E-03	1.338199E-03
15	G	1.071653E-02	-6.453034E-05	1.413663E-02	-9.900048E-04	-5.989461E-03	9.330001E-04
16	G	5.555075E-03	-3.358406E-05	8.216670E-03	-8.668930E-04	-4.563680E-03	5.441530E-04
17	G	2.468774E-03	-1.413906E-05	3.283310E-03	-6.839354E-04	-3.248961E-03	3.890113E-04
18	G	9.551497E-04	-6.387433E-06	-2.968531E-04	-8.317373E-04	-2.335243E-03	-5.332016E-04
19	G	7.068362E-02	-5.943434E-03	2.879180E-02	-1.672603E-03	-1.278269E-02	1.028005E-02
20	G	5.169261E-02	-3.937679E-03	2.747165E-02	-2.072313E-03	-1.161336E-02	7.673821E-03
21	G	3.631221E-02	-2.626021E-03	2.418071E-02	-2.594324E-03	-9.836334E-03	5.334102E-03
22	G	2.435236E-02	-1.700279E-03	1.976111E-02	-2.317133E-03	-8.162442E-03	3.846292E-03
23	G	1.536196E-02	-1.053460E-03	1.481306E-02	-2.302881E-03	-6.787670E-03	2.553011E-03
24	G	8.932310E-03	-6.057056E-04	9.886145E-03	-1.947311E-03	-5.443096E-03	1.753932E-03
25	G	4.634611E-03	-3.131132E-04	5.368509E-03	-1.692643E-03	-4.264296E-03	1.084766E-03
26	G	2.060113E-03	-1.376029E-04	1.596790E-03	-1.297075E-03	-3.067222E-03	7.109090E-04
27	G	7.977308E-04	-5.477712E-05	-1.142203E-03	-1.541375E-03	-2.401565E-03	-9.709962E-04
28	G	5.104025E-02	-1.644782E-02	1.360612E-02	-3.706443E-03	-9.454210E-03	1.212583E-02
29	G	3.735272E-02	-1.159913E-02	1.292242E-02	-4.084040E-03	-8.947507E-03	8.990065E-03
30	G	2.629264E-02	-7.982798E-03	1.119666E-02	-4.194769E-03	-7.969223E-03	6.595640E-03
31	G	1.765761E-02	-5.278479E-03	8.844945E-03	-3.713324E-03	-6.760233E-03	4.855642E-03
32	G	1.115223E-02	-3.303756E-03	6.202541E-03	-3.465826E-03	-5.800227E-03	3.305100E-03
33	G	6.488834E-03	-1.911786E-03	3.551309E-03	-2.924866E-03	-4.730257E-03	2.268499E-03
34	G	3.368570E-03	-9.900306E-04	1.113423E-03	-2.472434E-03	-3.798770E-03	1.343273E-03

??

0 SUBCASE 1

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
35	G	1.497048E-03	-4.382122E-04	-9.850079E-04	-1.874790E-03	-2.771883E-03	9.367254E-04
36	G	5.805509E-04	-1.713210E-04	-2.407279E-03	-2.049751E-03	-2.430600E-03	-1.252884E-03
37	G	3.204137E-02	-3.204137E-02	-3.890490E-03	-6.398147E-03	-6.398147E-03	1.257742E-02
38	G	2.320706E-02	-2.320706E-02	-3.890490E-03	-6.197170E-03	-6.197170E-03	9.626137E-03
39	G	1.623628E-02	-1.623628E-02	-3.890490E-03	-6.008810E-03	-6.008810E-03	7.041978E-03
40	G	1.085837E-02	-1.085837E-02	-3.890490E-03	-5.225623E-03	-5.225623E-03	5.188747E-03
41	G	6.841495E-03	-6.841495E-03	-3.890490E-03	-4.651490E-03	-4.651490E-03	3.568677E-03
42	G	3.974918E-03	-3.974918E-03	-3.890490E-03	-3.867494E-03	-3.867494E-03	2.446879E-03
43	G	2.082214E-03	-2.082214E-03	-3.890490E-03	-3.180169E-03	-3.180169E-03	1.469618E-03
44	G	9.154102E-04	-9.154102E-04	-3.890490E-03	-2.370913E-03	-2.370913E-03	1.014309E-03
45	G	3.558834E-04	-3.558834E-04	-3.890490E-03	-2.336390E-03	-2.336390E-03	-1.347534E-03
46	G	1.644782E-02	-5.104025E-02	-2.140618E-02	-9.464210E-03	-3.706443E-03	1.212683E-02
47	G	1.159913E-02	-3.736278E-02	-2.072142E-02	-8.947507E-03	-4.084048E-03	8.990856E-03
48	G	7.982790E-03	-2.629064E-02	-1.890588E-02	-7.958023E-03	-4.194769E-03	6.585640E-03
49	G	5.278479E-03	-1.765761E-02	-1.664394E-02	-6.750233E-03	-3.713324E-03	4.855542E-03
50	G	3.303756E-03	-1.115223E-02	-1.400154E-02	-5.800827E-03	-3.465826E-03	3.305100E-03
51	G	1.911786E-03	-6.488834E-03	-1.136030E-02	-4.730257E-03	-2.924866E-03	2.268490E-03
52	G	9.900306E-04	-3.368579E-03	-8.912421E-03	-3.782770E-03	-2.472434E-03	1.343873E-03
53	G	4.382122E-04	-1.497048E-03	-6.873390E-03	-2.771883E-03	-1.874790E-03	9.367254E-04
54	G	1.713210E-04	-5.805509E-04	-5.301718E-03	-2.430600E-03	-2.049751E-03	-1.252884E-03
55	G	5.943434E-03	-7.068362E-02	-3.859086E-02	-1.278289E-02	-1.572583E-03	1.029806E-02
56	G	3.937679E-03	-5.169261E-02	-3.527064E-02	-1.161336E-02	-2.072313E-03	7.573821E-03
57	G	2.626021E-03	-3.631221E-02	-3.197971E-02	-9.835334E-03	-2.594324E-03	5.334102E-03
58	G	1.700279E-03	-2.435236E-02	-2.755010E-02	-8.162462E-03	-2.317133E-03	3.845292E-03
59	G	1.053468E-03	-1.536196E-02	-2.261206E-02	-6.787676E-03	-2.302881E-03	2.553011E-03
60	G	6.057056E-04	-8.932318E-03	-1.768514E-02	-5.443095E-03	-1.947311E-03	1.753932E-03
61	G	3.131132E-04	-4.634611E-03	-1.316751E-02	-4.264295E-03	-1.692643E-03	1.024766E-03
62	G	1.376029E-04	-2.060113E-03	-9.395787E-03	-3.067222E-03	-1.297075E-03	7.199090E-04
63	G	5.477712E-05	-7.977308E-04	-6.668795E-03	-2.401555E-03	-1.541375E-03	-9.709962E-04
64	G	7.726308E-04	-8.770363E-02	-4.729052E-02	-1.662371E-02	1.278509E-05	7.472394E-03
65	G	4.552569E-04	-6.319187E-02	-4.540366E-02	-1.448311E-02	-1.890150E-03	4.415313E-03
66	G	2.955313E-04	-4.398698E-02	-4.088854E-02	-1.144960E-02	-1.553613E-03	2.913438E-03
67	G	1.843323E-04	-2.935179E-02	-3.496186E-02	-9.284242E-03	-1.266348E-03	2.030800E-03
68	G	1.135186E-04	-1.845969E-02	-2.841361E-02	-7.483871E-03	-1.216860E-03	1.338190E-03

0 SUBCASE 1

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
69	G	6.453034E-05	-1.071653E-02	-2.193663E-02	-5.929461E-03	-9.900048E-04	9.330091E-04
70	G	3.358400E-06	-5.555075E-03	-1.681587E-02	-4.563600E-03	-8.660938E-04	5.441538E-04
71	G	1.413900E-06	-8.468774E-03	-1.108231E-02	-3.848951E-03	-6.639364E-04	3.890113E-04
72	G	6.387433E-06	-9.561497E-04	-7.502144E-03	-2.336243E-03	-8.317373E-04	-5.330016E-04
73	G	.0	-9.544737E-02	-5.129615E-02	-1.906434E-02	.0	.0
74	G	.0	-6.788819E-02	-4.918783E-02	-1.563841E-02	.0	.0
75	G	.0	-4.695500E-02	-4.410803E-02	-1.804459E-02	.0	.0
76	G	.0	-3.183838E-02	-3.759020E-02	-9.686670E-03	.0	.0
77	G	.0	-1.960743E-02	-3.046690E-02	-7.780640E-03	.0	.0
78	G	.0	-1.137881E-02	-2.343421E-02	-6.100918E-03	.0	.0
79	G	.0	-5.892211E-03	-1.701756E-02	-4.663400E-03	.0	.0
80	G	.0	-2.618199E-03	-1.167400E-02	-3.311706E-03	.0	.0
81	G	.0	-1.012620E-03	-7.790907E-03	-2.302006E-03	.0	.0

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L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
3	G	1.[illegible]E+04	.0	.0	.0	.0	.0
13	G	.0	-1.[illegible]E+00	.0	.0	.0	.0

SUBCASE 1

F O R C E S O F S I N G L E - P O I N T C O N S T R A I N T

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	.0	5.081899E+00	.0	1.8458[illegible]E-01	.0	-1.328870E+00
2	G	.0	-5.298[illegible]E+00	.0	2.2[illegible]817E-01	.0	-1.428833E+00
3	G	.0	1.900775E+00	.0	2.8632[illegible]E-01	.0	-7.445798E-01
4	G	.0	-2.393496E-01	.0	4.8448[illegible]E-01	.0	-5.577105E-01
5	G	.0	[illegible].8879[illegible]E-01	.0	2.[illegible]E-01	.0	-4.184000E-01
6	G	.0	1.2274[illegible]E-01	.0	3.1[illegible]E-01	.0	-3.188498E-01
7	G	.0	4.6658[illegible]E-01	.0	3.243772E-01	.0	-2.400657E-01
8	G	.0	-1.[illegible]E+00	.0	3.671489E-01	.0	-1.872660E-01
9	G	.0	2.[illegible]E+00	5.101164E-09	2.077[illegible]E-01	.0	-8.606058E-02
[illegible]	G	-8.[illegible]E+00	.0	.0	.0	1.0458406E-01	-1.328879E+00
[illegible]	G	5.[illegible]E+00	.0	.0	.0	2.363817E-01	-1.428836E+00
[illegible]	G	-1.[illegible]E+00	.0	.0	.0	2.863258E-01	-7.445796E-01
[illegible]	G	2.[illegible]E-01	.0	.0	.0	2.844825E-01	-5.577105E-01
[illegible]	G	-[illegible].[illegible]E-01	.0	.0	.0	2.9233[illegible]E-01	-4.184000E-01
[illegible]	G	-1.227[illegible]E-01	.0	.0	.0	3.128480E-01	-3.188498E-01
[illegible]	G	-4.665[illegible]E-01	.0	.0	.0	3.243726E-01	-2.400657E-01
[illegible]	G	[illegible]E+00	.0	.0	.0	3.671490E-01	-1.872669E-01
[illegible]	G	-[illegible].[illegible]E+00	.0	.0	.0	2.077685E-01	-8.606062E-02

SUBCASE 1

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 4)
(IN STRESS COORDINATE SYSTEM)

ELEMENT ID	FIBRE DISTANCE	STRESSES IN STRESS COORD. SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
[illegible]	[illegible]	-1.351425E+03	3.756104E+03	-9.648372E+02	-79.0574	3.932077E+03	-1.687300E+03	2.728730E+03
	[illegible]	1.384571E+03	-1.236630E+03	9.520634E+02	10.0506	1.533360E+03	-4.006327E+03	2.770043E+03
[illegible]	[illegible]	-2.235944E+03	2.843473E+03	-4.557600E+02	-84.2491	2.880173E+03	-2.281843E+03	2.[illegible]E+03
	[illegible]	2.245990E+03	-2.088781E+03	4.623327E+02	6.0660	2.200630E+03	-2.144384E+03	2.281501E+03
[illegible]	[illegible]	-1.465083E+03	1.067362E+03	-2.400052E+02	-85.4874	1.088147E+03	-1.478660E+03	1.582752E+03
	[illegible]	1.469810E+03	-1.749730E+03	2.400078E+02	4.3000	1.480028E+03	-1.758743E+03	1.[illegible]E+03
[illegible]	[illegible]	-1.254757E+03	1.351647E+03	-1.303000E+02	-86.9434	1.360006E+03	-1.858100E+03	1.308844E+03
	[illegible]	1.257004E+03	-1.332775E+03	1.489864E+02	3.2334	1.264280E+03	-1.348040E+03	1.305164E+03
[illegible]	[illegible]	-1.644090E+03	1.138000E+03	-8.055811E+01	-87.8883	1.142878E+03	-1.047809E+03	1.093274E+03
	[illegible]	1.962759E+03	-1.150613E+03	5.154381E+01	2.1106	1.068810E+03	-1.153627E+03	1.104719E+03
[illegible]	[illegible]	-9.277065E+02	9.943210E+02	-4.895130E+01	-88.7219	9.962793E+02	-9.307640E+02	9.630170E+02
	[illegible]	9.372297E+02	-1.007742E+03	4.367456E+01	1.2857	9.382040E+02	-1.008722E+03	9.734816E+02
[illegible]	[illegible]	-8.808675E+02	9.468002E+02	-8.546034E+00	-89.7316	9.468843E+02	-8.808077E+02	9.134790E+02
	[illegible]	8.937796E+02	-9.264890E+02	8.638802E+00	.2525	8.938042E+02	-9.265244E+02	9.101582E+02
[illegible]	[illegible]	-5.411347E+02	1.043426E+03	2.107241E+01	89.2382	1.043746E+03	-5.414149E+02	7.925606E+02
	[illegible]	5.367614E+02	-1.067946E+03	-1.770681E+01	-.6325	5.369568E+02	-1.067236E+03	8.020963E+02
[illegible]	[illegible]	-1.156296E+03	1.744518E+03	-1.885135E+03	-63.7877	2.672723E+03	-2.084401E+03	2.378562E+03
	[illegible]	1.163627E+03	-1.811260E+03	1.252940E+03	25.6218	2.052336E+03	-2.699017E+03	2.378127E+03
[illegible]	[illegible]	-1.664650E+03	1.586165E+03	-1.210104E+03	-71.6663	1.987159E+03	-2.065644E+03	2.026401E+03
	[illegible]	1.672732E+03	-1.465032E+03	1.243612E+03	19.1837	2.105407E+03	-1.901707E+03	2.003557E+03
[illegible]	[illegible]	-1.284454E+03	1.346304E+03	-8.480399E+02	-73.1635	1.661832E+03	-1.457082E+03	1.520507E+03
	[illegible]	1.282654E+03	-1.407815E+03	8.446241E+02	16.4453	1.451785E+03	-1.650750E+03	1.554267E+03

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 4)
(IN STRESS COORDINATE SYSTEM)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN STRESS COORD. SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
[illegible]	[illegible]	-1.[illegible]E+03	1.158100E+03	-6.311615E+02	-76.1766	1.325177E+03	-1.227168E+03	1.[illegible]E+03
	[illegible]	1.082018E+03	-1.[illegible]E+03	3.342[illegible]E+02	14.3410	1.231300E+03	-1.315302E+03	1.273301E+03
[illegible]	[illegible]	-9.240653E+02	9.204930E+02	-4.380651E+02	-78.4632	1.118033E+03	-1.048806E+03	1.[illegible]E+03
	[illegible]	9.874662E+02	-1.000414E+03	4.910060E+02	13.4611	1.044858E+03	-1.125875E+03	1.088367E+03
[illegible]	[illegible]	-8.327751E+02	8.804076E+02	-4.004658E+02	-77.6386	8.780484E+02	-9.212958E+02	8.561168E+02
	[illegible]	8.775604E+02	-9.[illegible]E+02	4.007004E+02	12.7636	8.253026E+02	-8.804751E+02	8.578346E+02
[illegible]	[illegible]	-7.968327E+02	8.5[illegible]E+02	-3.288448E+02	-78.3282	9.181946E+02	-8.604037E+02	8.830691E+02
	[illegible]	8.106[illegible]E+02	-8.[illegible]784E+02	3.196102E+02	10.0871	8.706213E+02	-5.980444E+02	8.916322E+02
[illegible]	[illegible]	-5.006621E+02	8.779[illegible]E+02	-2.220472E+02	-81.3546	8.615145E+02	-6.348808E+02	7.475813E+02
	[illegible]	4.98[illegible]E+02	-8.[illegible]E+02	2.343060E+02	8.9877	5.354363E+02	-9.085485E+02	7.811434E+02
[illegible]	[illegible]	-5.[illegible]E+02	1.097434E+03	-1.961034E+03	-55.8544	2.337425E+03	-1.884455E+03	2.110737E+03
	[illegible]	5.222[illegible]E+02	-1.402872E+03	1.821085E+03	33.6823	1.832566E+03	-2.330815E+03	2.081307E+03
[illegible]	[illegible]	-1.[illegible]E+03	8.366482E+02	-1.521617E+03	-60.2323	1.624747E+03	-1.887379E+03	1.787313E+03
	[illegible]	1.04[illegible]E+03	-7.822074E+02	1.541523E+03	25.7731	1.886379E+03	-1.660424E+03	1.772238E+03
[illegible]	[illegible]	-9.[illegible]E+02	2.08[illegible]103E+02	-1.184[illegible]E+03	-62.1277	1.440246E+03	-1.449730E+03	1.444990E+03
	[illegible]	8.2835[illegible]E+02	-8.395[illegible]E+02	1.[illegible]129E+03	27.6222	1.456877E+03	-1.467035E+03	1.461956E+03
[illegible]	[illegible]	-7.[illegible]E+02	7.609322E+02	-9.[illegible]E+02	-63.9442	1.243161E+03	-1.213955E+03	1.[illegible]E+03
	[illegible]	[illegible]	-7.849681E+02	9.774478E+02	26.1357	1.227879E+03	-1.264590E+03	1.2[illegible]E+03
[illegible]	[illegible]	-6.7[illegible]E+02	7.8[illegible]E+02	-8.045492E+02	-[illegible].2224	1.072917E+03	-1.041447E+03	1.057182E+03
	[illegible]	6.751318E+02	-7.861284E+02	8.074981E+02	24.7195	1.047672E+03	-1.077921E+03	1.062827E+03
[illegible]	[illegible]	-6.122896E+02	6.482931E+02	-[illegible].872522E+02	-66.2623	9.605[illegible]E+02	-9.145179E+02	9.325163E+02
	[illegible]	6.173311E+02	-6.578905E+02	8.205163E+02	2[illegible].5891	9.181228E+02	-[illegible].588212E+02	9.384872E+02

SUBCASE 1

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 4)
(IN STRESS COORDINATE SYSTEM)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN STRESS COORD. SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
23	[illegible]	-5.2647696E+02	6.8673328E+02	-6.8438486E+02	-68.1564	8.6895686E+02	-8.3609977E+02	8.4592631E+02
	[illegible]	8.0438830E+02	-4.1331114E+02	3.7598228E+02	81.3045	8.3540377E+02	-4.4632687E+02	6.4008552E+02
24	[illegible]	-3.8445702E+02	8.7628796E+02	-4.3000958E+02	-76.4031	8.3418198E+02	-8.3785240E+02	8.3990775E+02
	[illegible]	3.7550443E+02	-5.5215996E+02	4.4096316E+02	19.8873	5.4894480E+02	-8.5138842E+02	7.0037386E+02
[illegible]	[illegible]	-8.2288327E+02	3.4864098E+02	-2.0438877E+03	-48.7737	2.1254306E+03	-2.0007004E+03	2.0635877E+03
	[illegible]	2.1857432E+02	-3.6110815E+02	2.0170001E+03	40.0111	1.9685225E+02	-2.1601885E+03	2.0378146E+03
[illegible]	[illegible]	-3.6664472E+02	3.6256031E+02	-1.6873856E+03	-51.7011	1.7158214E+03	-1.7588682E+03	1.7620863E+03
	[illegible]	3.5827122E+02	-3.6362796E+02	1.6794862E+03	[illegible]	1.7141846E+03	-1.7186825E+03	1.7188742E+03
27	[illegible]	-3.5223308E+02	3.5049775E+02	-1.3715646E+03	[illegible].1045	1.4149377E+03	-1.4167288E+03	1.4158856E+03
	[illegible]	3.4715468E+02	-3.5885146E+02	1.3723865E+03	37.8882	1.4145386E+03	-1.4868870E+03	1.4295808E+03
28	[illegible]	-3.4623697E+02	[illegible]4632076E+02	-1.1584552E+03	-53.2369	1.2106365E+03	-1.2095370E+03	1.2088038E+03
	[illegible]	3.3250906E+02	-3.3392795E+02	1.1821065E+03	33.8206	1.2068893E+03	-1.2133946E+03	1.2111143E+03
[illegible]	[illegible]	-3.2562682E+02	3.3194682E+02	-9.9082437E+02	-54.1686	1.0446667E+03	-1.0412212E+03	1.0439244E+03
	[illegible]	3.2421071E+02	-3.3055024E+02	9.2548868E+02	35.8367	1.0458436E+03	-1.0518938E+03	1.0485577E+03
[illegible]	[illegible]	-3.[illegible]E+02	3.1943408E+02	-8.6080615E+02	-54.9303	9.2798856E+02	-9.1382896E+02	9.2181832E+02
	[illegible]	3.9027946E+02	-3.2313311E+02	8.5329706E+02	34.9977	9.1208598E+02	-9.3104888E+02	9.2491726E+02
[illegible]	[illegible]	-3.3608997E+02	3.1127425E+02	-7.5556631E+02	-56.6628	5.2058844E+02	-8.1152156E+02	8.1605404E+02
	[illegible]	3.9621462E+02	-3.0642846E+02	7.5125052E+02	33.9277	8.1838226E+02	-8.1177676E+02	8.1187966E+02
32	[illegible]	-3.1169192E+02	3.1272688E+02	-6.7257755E+02	-57.3834	3.9824196E+02	-5.7929706E+02	6.2972456E+02
	[illegible]	3.1506642E+02	-3.8109875E+02	5.9659284E+02	32.8822	6.6078455E+02	-7.9762082E+02	6.5418256E+02
[illegible]	[illegible]	[illegible]E+02	-2.8541656E+02	-2.8515896E+03	-41.5915	2.8887945E+03	-2.1224348E+03	2.8835676E+03
	[illegible]	-1.5635962E+02	2.8056275E+02	2.0250630E+03	48.3676	2.1891656E+03	-1.9466222E+03	2.9378146E+03

SUBCASE 1

S T R E S S E S I N G E N E R A L Q U A D R I L A T E R A L E L E M E N T S (Q U A D 4)
(IN STRESS COORDINATE SYSTEM)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN STRESS COORD. SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
34	-2.500000E-02	1.126915E+02	-1.285471E+02	1.604393E+03	-41.2818	1.700953E+03	-1.715814E+03	1.708383E+03
	2.500000E-02	-2.033550E+02	2.087607E+02	1.704463E+03	45.4464	1.719682E+03	-1.714166E+03	1.716874E+03
35	-2.500000E-02	1.432203E+02	-1.414856E+02	-1.429566E+03	-45.1148	1.416732E+03	-1.414907E+03	1.416654E+03
	2.500000E-02	-1.374077E+02	1.496842E+02	1.411344E+03	47.5886	1.485837E+03	-1.414536E+03	1.486595E+03
36	-2.500000E-02	9.710633E+01	-1.021887E+02	-1.263984E+03	-42.6353	1.286638E+03	-1.216634E+03	1.256630E+03
	2.500000E-02	-9.525290E+01	8.975436E+01	1.607718E+03	47.3008	1.213394E+03	-1.259893E+03	1.211103E+03
37	-2.500000E-02	8.524464E+01	-7.085488E+01	-1.041709E+03	-43.1336	1.041821E+03	-1.046087E+03	1.045044E+03
	2.500000E-02	-6.537303E+01	7.882182E+01	1.046364E+03	46.8618	1.051982E+03	-1.045843E+03	1.048567E+03
38	-2.500000E-02	3.873666E+01	-2.371714E+01	-9.207326E+02	-43.6095	9.153260E+02	-9.876008E+02	9.218163E+02
	2.500000E-02	-3.383002E+01	5.303381E+01	9.828517E+02	48.4536	9.310485E+02	-9.169859E+02	9.240172E+02
39	-2.500000E-02	3.744352E+01	-4.850056E+01	-8.149737E+02	-[illegible].5258	8.115215E+02	-8.205834E+02	8.160540E+02
	2.500000E-02	-4.139755E+01	4.270163E+01	8.090906E+02	46.4843	8.117757E+02	-8.103822E+02	8.116756E+02
40	-2.500000E-02	-8.516096E+00	-9.251068E+01	-6.883222E+02	-43.8878	5.792070E+02	-6.896412E+02	6.287245E+02
	2.500000E-02	1.485616E+01	9.286611E+01	6.539749E+02	46.7286	7.078568E+02	-6.007045E+02	6.541828E+02
41	-2.500000E-02	4.133648E+02	-3.467496E+02	-1.984112E+03	-35.0366	1.884946E+03	-2.337428E+03	2.110737E+03
	2.500000E-02	-4.327583E+02	3.904143E+02	1.944794E+03	55.4364	2.330215E+03	-1.832566E+03	2.081387E+03
42	-2.500000E-02	8.982154E+02	-4.930077E+02	-1.690445E+03	-31.7838	1.885978E+03	-1.634747E+03	1.787313E+03
	2.500000E-02	-7.990622E+02	6.235074E+02	1.517917E+03	57.6047	1.856034E+03	-1.826379E+03	1.798237E+03
43	-2.500000E-02	6.344911E+02	-6.289021E+02	-1.282519E+03	-32.1716	1.446739E+03	-1.440240E+03	1.444990E+03
	2.500000E-02	-6.394619E+02	6.495586E+02	1.312235E+03	58.8786	1.457035E+03	-1.466877E+03	1.461956E+03
44	-2.500000E-02	6.247728E+02	-5.148758E+02	-1.162846E+03	-31.8670	1.213954E+03	-1.243161E+03	1.228558E+03
	2.500000E-02	-5.327285E+02	5.582483E+02	1.118628E+03	57.9931	1.244593E+03	-1.227079E+03	1.235823E+03

S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 4)
(IN STRESS COORDINATE SYSTEM)

ELEMENT ID.	FIBRE DISTANCE	STRESSES IN STRESS COORD. SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
45	-2.000000E-02	4.451425E+02	-4.766131E+02	-9.514336E+02	-32.0771	1.041447E+03	-1.072917E+03	1.057182E+03
	2.000000E-02	-4.502843E+02	4.803330E+02	9.556343E+02	57.9810	1.077921E+03	-1.047878E+03	1.062897E+03
46	-2.000000E-02	3.823891E+02	-4.183863E+02	-8.421855E+02	-32.2064	9.145170E+02	-9.506149E+02	9.325163E+02
	2.000000E-02	-3.867291E+02	4.272970E+02	8.456461E+02	57.8622	9.588916E+02	-9.181828E+02	9.384072E+02
47	-2.000000E-02	3.700093E+02	-4.008664E+02	-7.528106E+02	-31.4318	8.300997E+02	-8.609568E+02	8.455282E+02
	2.000000E-02	-3.801053E+02	3.890284E+02	7.477718E+02	58.0080	8.453867E+02	-8.364637E+02	8.409252E+02
48	-2.000000E-02	1.974446E+02	-4.839641E+02	-5.895409E+02	-29.9881	5.376624E+02	-8.241819E+02	6.809072E+02
	2.000000E-02	-1.907107E+02	4.935763E+02	6.111146E+02	59.6215	8.510864E+02	-5.489400E+02	7.003730E+02
49	-2.000000E-02	1.097029E+03	-1.685951E+03	-1.900865E+03	-27.0936	2.084401E+03	-2.672723E+03	2.378562E+03
	2.000000E-02	-1.106993E+03	1.753674E+03	1.897814E+03	63.4969	2.699917E+03	-2.052336E+03	2.376127E+03
50	-2.000000E-02	1.547234E+03	-1.468749E+03	-1.363611E+03	-28.9560	2.065644E+03	-1.987159E+03	2.026401E+03
	2.000000E-02	-1.552481E+03	1.348781E+03	1.381995E+03	68.1940	1.901707E+03	-2.105407E+03	2.003557E+03
51	-2.000000E-02	1.059356E+03	-1.204200E+03	-1.020817E+03	-21.1368	1.457082E+03	-1.601932E+03	1.529507E+03
	2.000000E-02	-1.061789E+03	1.266756E+03	1.029669E+03	69.2554	1.656750E+03	-1.461785E+03	1.554267E+03
52	-2.000000E-02	9.084793E+02	-1.006644E+03	-8.436990E+02	-20.6988	1.227162E+03	-1.325177E+03	1.276170E+03
	2.000000E-02	-9.098086E+02	9.938111E+02	8.457856E+02	69.1877	1.315302E+03	-1.231300E+03	1.273301E+03
53	-2.000000E-02	7.690019E+02	-8.444304E+02	-7.185308E+02	-20.8467	1.042605E+03	-1.118033E+03	1.080319E+03
	2.000000E-02	-7.723681E+02	8.533844E+02	7.192034E+02	69.2494	1.125875E+03	-1.044859E+03	1.085367E+03
54	-2.000000E-02	6.769612E+02	-7.345896E+02	-6.360739E+02	-21.0132	9.212958E+02	-9.789242E+02	9.501100E+02
	2.000000E-02	-6.813014E+02	7.463837E+02	6.388007E+02	69.0877	9.904751E+02	-9.253928E+02	9.579340E+02
55	-2.000000E-02	6.479016E+02	-6.995323E+02	-5.758900E+02	-20.2618	8.604937E+02	-9.121245E+02	8.863091E+02
	2.000000E-02	-6.600838E+02	6.821069E+02	5.717583E+02	69.7849	8.926444E+02	-8.708213E+02	8.816329E+02

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SUBCASE 1

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S T R E S S E S   I N   G E N E R A L   Q U A D R I L A T E R A L   E L E M E N T S   (C Q U A D 4)

(IN STRESS COORDINATE SYSTEM)

	ELEMENT ID.	FIBRE DISTANCE	STRESSES IN STRESS COORD. SYSTEM NORMAL-X	NORMAL-Y	SHEAR-XY	PRINCIPAL STRESSES (ZERO SHEAR) ANGLE	MAJOR	MINOR	MAX SHEAR
0	56	-2.000000E-02	3.753148E+02	-8.025401E+02	-4.610000E+02	-19.0266	5.342892E+02	-9.615145E+02	7.479018E+02
		2.000000E-02	-3.681661E+02	8.195762E+02	4.700844E+02	70.8411	9.808486E+02	-5.364383E+02	7.611434E+02
0	57	-2.000000E-02	1.320560E+03	-3.725239E+03	-1.042327E+03	-11.2230	1.527398E+03	-3.932077E+03	2.729738E+03
		2.000000E-02	-1.334060E+03	3.800010E+03	1.031884E+03	79.0679	4.008327E+03	-1.533369E+03	2.770843E+03
0	58	-2.000000E-02	2.184909E+03	-2.192430E+03	-6.586467E+02	-8.3732	2.281843E+03	-2.389373E+03	2.285608E+03
		2.000000E-02	-2.190630E+03	2.044306E+03	6.590113E+02	[illegible].3717	2.144364E+03	-2.200630E+03	2.221501E+03
0	59	-2.000000E-02	1.404372E+03	-1.612561E+03	-4.792038E+02	-8.5119	1.470658E+03	-1.606847E+03	1.582753E+03
		2.000000E-02	-1.414632E+03	1.694553E+03	4.859783E+02	81.3808	1.760743E+03	-1.480028E+03	1.620782E+03
0	60	-2.000000E-02	1.196164E+03	-1.296064E+03	-4.012553E+02	-8.9278	1.258199E+03	-1.359008E+03	1.308644E+03
		2.000000E-02	-1.202920E+03	1.276679E+03	4.078502E+02	80.8953	1.342040E+03	-1.268289E+03	1.305164E+03
0	61	-2.000000E-02	9.893726E+02	-1.081381E+03	-3.629219E+02	-9.4112	1.047869E+03	-1.139878E+03	1.093874E+03
		2.000000E-02	-9.966730E+02	1.094490E+03	3.605900E+02	80.5840	1.153627E+03	-1.065810E+03	1.104718E+03
0	62	-2.000000E-02	8.746513E+02	-9.391759E+02	-3.230974E+02	-9.8269	9.307548E+02	-9.968793E+02	9.638170E+02
		2.000000E-02	-8.814023E+02	9.519237E+02	3.276529E+02	80.1656	1.008722E+03	-9.382009E+02	9.734616E+02
0	63	-2.000000E-02	8.265627E+02	-8.938854E+02	-3.081236E+02	-9.8565	8.800977E+02	-9.468603E+02	9.134790E+02
		2.000000E-02	-8.406327E+02	8.733512E+02	3.065380E+02	80.1592	9.265244E+02	-8.938060E+02	9.101652E+02
0	64	-2.000000E-02	4.970617E+02	-9.993533E+02	-2.614152E+02	-9.6294	5.414149E+02	-1.043706E+03	7.925606E+02
		2.000000E-02	-4.908683E+02	1.021147E+03	2.679753E+02	80.2413	1.067236E+03	-5.369568E+02	8.020963E+02

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PROBLEM #10

N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

```
ID JAI,NASTRAN PROBLEM 3
SOL 1,0
APP DISP
TIME 100
CEND
```

```
QUAD4 COMPOSITE TUBE                                        MARCH 23, 1989   RELEASE 1988 CDC   PAGE    2
SYMMETRIC LAYUP [45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE P
                        C A S E   C O N T R O L   D E C K   E C H O
 CARD
 COUNT
        TITLE = QUAD4 COMPOSITE TUBE
        SUBTITLE = SYMMETRIC LAYUP [45/-45/0/90]S
        LABEL = TUBE UNDER CONSTANT PRESSURE P
        $
        $
        $    MODEL: SECTION OF A OPEN TUBE RADIUS R, UNDER PRESSURE P.
        $           SYMMETRIC LAYUP [45/-45/0/90/90/0/-45/45]
        $
        $     * * COMPARISON OF HOOP LOADING FY FOR ELEMENT ID 8 * *
        $
        $
        $       HOOP LOADING FY = P * R = 10.5 * 50 = 5.25E5
        $
        $       UAI/NASTRAN       MSC/NASTRAN       THEORETICAL
        $       -----------------------------------------------
        $       5.15E2            5.15E2            5.25E2
        $
        $
        $     * * COMPARISON OF LAYER STRESSES FOR ELEMENT ID 8 * *
        $
        $                           UAI/NASTRAN
        $
        $     ----------------------------------------------------
        $                   SIG1             SIG2        TAU12
        $       LAYER 1   2.524E2          1.741E1      2.277E1
        $       LAYER 2   2.494E2          1.751E1     -2.276E1
        $       LAYER 3  -2.259E2          3.231E1      1.944E-2
        $       LAYER 4   7.271E2          2.652E0      1.556E-2
        $       LAYER 5   7.270E2          2.560E0      5.854E-2
        $       LAYER 6  -2.253E2          3.230E1     -8.551E-2
        $       LAYER 7   2.534E2          1.741E1     -2.273E1
        $       LAYER 8   2.477E2          1.759E1      2.272E1
        $
        $
        $                           MSC/NASTRAN
QUAD4 COMPOSITE TUBE                                        MARCH 23, 1989   RELEASE 1988 CDC   PAGE    3
SYMMETRIC LAYUP [45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE P
                        C A S E   C O N T R O L   D E C K   E C H O
 CARD
 COUNT
        $     ----------------------------------------------------
        $                   SIG1             SIG2        TAU12
        $       LAYER 1   2.519E2          1.740E1      2.273E1
        $       LAYER 2   2.494E2          1.748E1     -2.273E1
        $       LAYER 3  -2.257E2          3.228E1      1.198E-2
        $       LAYER 4   7.268E2          2.651E0      2.221E-2
        $       LAYER 5   7.269E2          2.657E0      5.551E-2
        $       LAYER 6  -2.255E2          3.231E1     -8.881E-2
        $       LAYER 7   2.535E2          1.741E1     -2.274E1
        $       LAYER 8   2.478E2          1.760E1      2.274E1
        $
        $
        $
        SPC = 1
        SET 1 = 29,45,61,77
        SET 2 = 8,24
        DISP(PRINT) = 1
```

```
        52      STRESS(LAYER) = 2
        53      FORCE(PRINT) = 2
        54      SUBCASE 1
        55        LOAD = 1
        56      BEGIN BULK
QUAD4 COMPOSITE TUBE                                                          MARCH  23, 1989   RELEASE  1988  CDC    PAGE     4
SYMMETRIC LAYUP [45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE P

*** USER INFORMATION MESSAGE 207,  BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
QUAD4 COMPOSITE TUBE                                                          MARCH  23, 1989   RELEASE  1988  CDC    PAGE     5
SYMMETRIC LAYUP [45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE P
                                        S O R T E D   B U L K   D A T A   E C H O
       CARD
       COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
          1-        CORD2C  1               0.0     0.0     0.0     0.0     0.0     1.0     +MOR1001
          2-        +MOR10011.0     0.0     0.0
          3-        CORD2R  2       1       50.0    0.0     0.0     40.0    0.0     0.0     +ABC
          4-        +ABC    50.0    0.0     1.0
          5-        CQUAD4  1       2       17      33      35      19      2
          6-        CQUAD4  2       2       19      35      37      21      2
          7-        CQUAD4  3       2       17      18      34      33      2
          8-        CQUAD4  4       2       18      20      36      34      2
          9-        CQUAD4  5       2       24      26      42      40      2
         10-        CQUAD4  6       2       26      28      44      42      2
         11-        CQUAD4  7       2       24      40      38      22      2
         12-        CQUAD4  8       2       22      38      36      20      2
         13-        CQUAD4  9       2       25      23      39      41      2
         14-        CQUAD4  10      2       23      21      37      39      2
         15-        CQUAD4  11      2       25      41      43      27      2
         16-        CQUAD4  12      2       27      43      45      29      2
         17-        CQUAD4  13      2       32      48      46      30      2
         18-        CQUAD4  14      2       30      46      44      28      2
         19-        CQUAD4  15      2       32      31      47      48      2
         20-        CQUAD4  16      2       31      29      45      47      2
         21-        CQUAD4  17      2       33      49      51      35      2
         22-        CQUAD4  18      2       35      51      53      37      2
         23-        CQUAD4  19      2       33      34      50      49      2
         24-        CQUAD4  20      2       34      36      52      50      2
         25-        CQUAD4  21      2       40      42      58      56      2
         26-        CQUAD4  22      2       42      44      60      58      2
         27-        CQUAD4  23      2       40      56      54      38      2
         28-        CQUAD4  24      2       38      54      52      36      2
         29-        CQUAD4  25      2       41      39      55      57      2
         30-        CQUAD4  26      2       39      37      53      55      2
         31-        CQUAD4  27      2       41      57      59      43      2
         32-        CQUAD4  28      2       43      59      61      45      2
         33-        CQUAD4  29      2       48      64      62      46      2
         34-        CQUAD4  30      2       46      62      60      44      2
QUAD4 COMPOSITE TUBE                                                          MARCH  23, 1989   RELEASE  1988  CDC    PAGE     6
SYMMETRIC LAYUP [45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE P
                                        S O R T E D   B U L K   D A T A   E C H O
       CARD
       COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
         35-        CQUAD4  31      2       43      47      63      64      2
         36-        CQUAD4  32      2       47      45      61      63      2
         37-        CQUAD4  33      2       49      65      67      51      2
         38-        CQUAD4  34      2       51      67      69      53      2
         39-        CQUAD4  35      2       49      50      66      65      2
         40-        CQUAD4  36      2       50      52      68      66      2
```

```
  41-        CQUAD4  37      2       56      58      74      72      2
  42-        CQUAD4  38      2       58      60      76      74      2
  43-        CQUAD4  39      2       53      72      [illegible] 54  2
  44-        CQUAD4  40      2       54      70      68      52      2
  45-        CQUAD4  41      2       57      55      71      73      2
  46-        CQUAD4  42      2       55      53      69      71      2
  47-        CQUAD4  43      2       57      73      75      59      2
  48-        CQUAD4  44      2       59      75      77      61      2
  49-        CQUAD4  45      2       64      80      78      62      2
  50-        CQUAD4  46      2       62      78      76      60      2
  51-        CQUAD4  47      2       64      63      79      80      2
  52-        CQUAD4  48      2       63      61      77      79      2
  53-        CQUAD4  49      2       65      81      83      67
  54-        CQUAD4  50      2       67      83      85      69      2
  55-        CQUAD4  51      2       65      66      82      81      2
  56-        CQUAD4  52      2       66      68      84      82      2
  57-        CQUAD4  53      2       72      74      90      88      2
  58-        CQUAD4  54      2       74      76      92      90      2
  59-        CQUAD4  55      2       72      88      86      70      2
  60-        CQUAD4  56      2       70      86      84      68      2
  61-        CQUAD4  57      2       73      71      87      89      2
  62-        CQUAD4  58      2       71      69      85      87      2
  63-        CQUAD4  59      2       73      89      91      75      2
  64-        CQUAD4  60      2       75      91      93      77      2
  65-        CQUAD4  61      2       80      96      94      78      2
  66-        CQUAD4  62      2       78      94      92      76      2
  67-        CQUAD4  63      2       80      79      95      96      2
  68-        CQUAD4  64      2       79      77      97      95      2
QUAD4 COMPOSITE TUBE                                               MARCH 23, 1989    RELEASE 1988 CDC    PAGE     7
SYMMETRIC LAYUP [45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE

                                      S O R T E D   B U L K   D A T A   E C H O
 CARD
 COUNT       ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
  69-        CQUAD4  65      2       81      97      99      83      2
  70-        CQUAD4  66      2       83      99      101     85      2
  71-        CQUAD4  67      2       81      82      98      97      2
  72-        CQUAD4  68      2       82      84      100     98      2
  73-        CQUAD4  69      2       88      90      106     104     2
  74-        CQUAD4  70      2       90      92      108     106     2
  75-        CQUAD4  71      2       88      104     102     86      2
  76-        CQUAD4  72      2       86      102     100     84      2
  77-        CQUAD4  73      2       89      87      103     105     2
  78-        CQUAD4  74      2       87      85      101     103     2
  79-        CQUAD4  75      2       89      105     107     91      2
  80-        CQUAD4  76      2       91      107     109     93      2
  81-        CQUAD4  77      2       96      112     110     94      2
  82-        CQUAD4  78      2       94      110     108     92      2
  83-        CQUAD4  79      2       96      95      111     112     2
  84-        CQUAD4  80      2       95      93      109     111     2
  85-        CQUAD4  81      2       97      113     115     99      2
  86-        CQUAD4  82      2       99      115     117     101     2
  87-        CQUAD4  83      2       97      98      114     113     2
  88-        CQUAD4  84      2       98      100     116     114     2
  89-        CQUAD4  85      2       104     106     122     120     2
  90-        CQUAD4  86      2       106     108     124     122     2
  91-        CQUAD4  87      2       104     120     118     102     2
  92-        CQUAD4  88      2       102     118     116     100     2
  93-        CQUAD4  89      2       105     103     119     121     2
  94-        CQUAD4  90      2       103     101     117     119     2
  95-        CQUAD4  91      2       105     121     123     107     2
  96-        CQUAD4  92      2       107     123     125     109     2
  97-        CQUAD4  93      2       112     128     126     110     2
```

98-	CQUAD4	94	2	110	126	124	108	2
99-	CQUAD4	95	2	112	111	127	128	2
100-	CQUAD4	96	2	111	109	125	127	2
101-	CQUAD4	97	2	113	129	131	115	2
102-	CQUAD4	98	2	115	131	133	117	2

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
103-	CQUAD4	99	2	113	114	130	129	2		
104-	CQUAD4	100	2	114	116	132	130	2		
105-	CQUAD4	101	2	120	122	138	136	2		
106-	CQUAD4	102	2	122	124	140	138	2		
107-	CQUAD4	103	2	120	136	134	118	2		
108-	CQUAD4	104	2	118	134	132	116	2		
109-	CQUAD4	105	2	121	119	135	137	2		
110-	CQUAD4	106	2	119	117	133	135	2		
111-	CQUAD4	107	2	121	137	139	123	2		
112-	CQUAD4	108	2	123	139	141	125	2		
113-	CQUAD4	109	2	128	144	142	126	2		
114-	CQUAD4	110	2	126	142	140	124	2		
115-	CQUAD4	111	2	128	127	143	144	2		
116-	CQUAD4	112	2	127	125	141	143	2		
117-	CQUAD4	113	2	1	17	19	3	2		
118-	CQUAD4	114	2	3	19	21	5	2		
119-	CQUAD4	115	2	1	2	18	17	2		
120-	CQUAD4	116	2	2	4	20	18	2		
121-	CQUAD4	117	2	8	10	26	24	2		
122-	CQUAD4	118	2	10	12	28	26	2		
123-	CQUAD4	119	2	8	24	22	6	2		
124-	CQUAD4	120	2	6	22	20	4	2		
125-	CQUAD4	121	2	9	7	23	25	2		
126-	CQUAD4	122	2	7	5	21	23	2		
127-	CQUAD4	123	2	9	25	27	11	2		
128-	CQUAD4	124	2	11	27	29	13	2		
129-	CQUAD4	125	2	16	32	30	14	2		
130-	CQUAD4	126	2	12	30	28	12	2		
131-	CQUAD4	127	2	16	15	31	32	2		
132-	CQUAD4	128	2	15	13	29	31	2		
133-	GRID	1	1	50.000	180.000	0.000				
134-	GRID	2	1	50.000	202.500	0.000				
135-	GRID	3	1	50.000	157.500	0.000				
136-	GRID	4	1	50.000	225.000	0.000				

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
137-	GRID	5	1	50.000	135.000	0.000				
138-	GRID	6	1	50.000	247.500	0.000				
139-	GRID	7	1	50.000	112.500	0.000				
140-	GRID	8	1	50.000	270.000	0.000				
141-	GRID	9	1	50.000	90.000	0.000				
142-	GRID	10	1	50.000	292.500	0.000				
143-	GRID	11	1	50.000	67.500	0.000				
144-	GRID	12	1	50.000	315.000	0.000				
145-	GRID	13	1	50.000	45.000	0.000				
146-	GRID	14	1	50.000	337.500	0.000				
147-	GRID	15	1	50.000	22.500	0.000				
148-	GRID	16	1	50.000	0.000	0.000				

149-	GRID	17	1	50.000	180.000	10.000
150-	GRID	18	1	50.000	202.500	10.000
151-	GRID	19	1	50.000	157.500	10.000
152-	GRID	20	1	50.000	225.000	10.000
153-	GRID	21	1	50.000	135.000	10.000
154-	GRID	22	1	50.000	247.500	10.000
155-	GRID	23	1	50.000	112.500	10.000
156-	GRID	24	1	50.000	270.000	10.000
157-	GRID	25	1	50.000	90.000	10.000
158-	GRID	26	1	50.000	292.500	10.000
159-	GRID	27	1	50.000	67.500	10.000
160-	GRID	28	1	50.000	315.000	10.000
161-	GRID	29	1	50.000	45.000	10.000
162-	GRID	30	1	50.000	337.500	10.000
163-	GRID	31	1	50.000	22.500	10.000
164-	GRID	32	1	50.000	0.000	10.000
165-	GRID	33	1	50.000	180.000	20.000
166-	GRID	34	1	50.000	202.500	20.000
167-	GRID	35	1	50.000	157.500	20.000
168-	GRID	36	1	50.000	225.000	20.000
169-	GRID	37	1	50.000	135.000	20.000
170-	GRID	38	1	50.000	247.500	20.000

QUAD4 COMPOSITE TUBE
SYMMETRIC LAYUP (45/-45/0/90)S
... UNDER CONSTANT PRESSURE P

S O R T E D B U L K D A T A E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++
171-	GRID	39	1	50.000	112.500	20.000
172-	GRID	40	1	50.000	270.000	20.000
173-	GRID	41	1	50.000	90.000	20.000
174-	GRID	42	1	50.000	292.500	20.000
175-	GRID	43	1	50.000	67.500	20.000
176-	GRID	44	1	50.000	315.000	20.000
177-	GRID	45	1	50.000	45.000	20.000
178-	GRID	46	1	50.000	337.500	20.000
179-	GRID	47	1	50.000	22.500	20.000
180-	GRID	48	1	50.000	0.000	20.000
181-	GRID	49	1	50.000	180.000	30.000
182-	GRID	50	1	50.000	202.500	30.000
183-	GRID	51	1	50.000	157.500	30.000
184-	GRID	52	1	50.000	225.000	30.000
185-	GRID	53	1	50.000	135.000	30.000
186-	GRID	54	1	50.000	247.500	30.000
187-	GRID	55	1	50.000	112.500	30.000
188-	GRID	56	1	50.000	270.000	30.000
189-	GRID	57	1	50.000	90.000	30.000
190-	GRID	58	1	50.000	292.500	30.000
191-	GRID	59	1	50.000	67.500	30.000
192-	GRID	60	1	50.000	315.000	30.000
193-	GRID	61	1	50.000	45.000	30.000
194-	GRID	62	1	50.000	337.500	30.000
195-	GRID	63	1	50.000	22.500	30.000
196-	GRID	64	1	50.000	0.000	30.000
197-	GRID	65	1	50.000	180.000	40.000
198-	GRID	66	1	50.000	202.500	40.000
199-	GRID	67	1	50.000	157.500	40.000
200-	GRID	68	1	50.000	225.000	40.000
201-	GRID	69	1	50.000	135.000	40.000
202-	GRID	70	1	50.000	247.500	40.000
203-	GRID	71	1	50.000	112.500	40.000
204-	GRID	72	1	50.000	270.000	40.000

---7--- +++8+++ ---9--- +++10+++

QUAD4 COMPOSITE TUBE

SYMMETRIC LAYUP C45 -45/0/90]S
TUBE UNDER CONSTANT PRESSURE P

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
205-	GRID	73	1	50.000	90.000	40.000				
206-	GRID	74	1	50.000	292.500	40.000				
207-	GRID	75	1	50.000	67.500	40.000				
208-	GRID	76	1	50.000	315.000	40.000				
209-	GRID	77	1	50.000	45.000	40.000				
210-	GRID	78	1	50.000	337.500	40.000				
211-	GRID	79	1	50.000	22.500	40.000				
212-	GRID	80	1	50.000	0.000	40.000				
213-	GRID	81	1	50.000	180.000	50.000				
214-	GRID	82	1	50.000	202.500	50.000				
215-	GRID	83	1	50.000	157.500	50.000				
216-	GRID	84	1	50.000	225.000	50.000				
217-	GRID	85	1	50.000	135.000	50.000				
218-	GRID	86	1	50.000	247.500	50.000				
219-	GRID	87	1	50.000	112.500	50.000				
220-	GRID	88	1	50.000	270.000	50.000				
221-	GRID	89	1	50.000	90.000	50.000				
222-	GRID	90	1	50.000	292.500	50.000				
223-	GRID	91	1	50.000	67.500	50.000				
224-	GRID	92	1	50.000	315.000	50.000				
225-	GRID	93	1	50.000	45.000	50.000				
226-	GRID	94	1	50.000	337.500	50.000				
227-	GRID	95	1	50.000	22.500	50.000				
228-	GRID	96	1	50.000	0.000	50.000				
229-	GRID	97	1	50.000	180.000	60.000				
230-	GRID	98	1	50.000	202.500	60.000				
231-	GRID	99	1	50.000	157.500	60.000				
232-	GRID	100	1	50.000	225.000	60.000				
233-	GRID	101	1	50.000	135.000	60.000				
234-	GRID	102	1	50.000	247.500	60.000				
235-	GRID	103	1	50.000	112.500	60.000				
236-	GRID	104	1	50.000	270.000	60.000				
237-	GRID	105	1	50.000	90.000	60.000				
238-	GRID	106	1	50.000	292.500	60.000				

GRAPHITE COMPOSITE TUBE
SYMMETRIC LAYUP C45/-45/0/90]S
TUBE UNDER CONSTANT PRESSURE P

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
239-	GRID	107	1	50.000	67.500	60.000				
240-	GRID	108	1	50.000	315.000	60.000				
241-	GRID	109	1	50.000	45.000	60.000				
242-	GRID	110	1	50.000	337.500	60.000				
243-	GRID	111	1	50.000	22.500	60.000				
244-	GRID	112	1	50.000	0.000	60.000				
245-	GRID	113	1	50.000	180.000	70.000				
246-	GRID	114	1	50.000	202.500	70.000				
247-	GRID	115	1	50.000	157.500	70.000				
248-	GRID	116	1	50.000	225.000	70.000				
249-	GRID	117	1	50.000	135.000	70.000				
250-	GRID	118	1	50.000	247.500	70.000				
251-	GRID	119	1	50.000	112.500	70.000				
252-	GRID	120	1	50.000	270.000	70.000				
253-	GRID	121	1	50.000	90.000	70.000				
254-	GRID	122	1	50.000	292.500	70.000				
255-	GRID	123	1	50.000	67.500	70.000				
256-	GRID	124	1	50.000	315.000	70.000				

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      257-        GRID    125     1         50.000   45.000  70.000
      258-        GRID    126     1         50.000   337.500 70.000
      259-        GRID    127     1         50.000   22.500  70.000
      260-        GRID    128     1         50.000   0.000   70.000
      261-        GRID    129     1         50.000   180.000 80.000
      262-        GRID    130     1         50.000   202.500 80.000
      263-        GRID    131     1         50.000   157.500 80.000
      264-        GRID    132     1         50.000   225.000 80.000
      265-        GRID    133     1         50.000   135.000 80.003
      266-        GRID    134     1         50.000   247.500 80.000
      267-        GRID    135     1         50.000   112.500 80.000
      268-        GRID    136     1         50.000   270.000 80.000
      269-        GRID    137     1         50.000   90.000  80.000
      270-        GRID    138     1         50.000   292.500 80.000
      271-        GRID    139     1         50.000   67.500  80.000
      272-        GRID    140     1         50.000   315.000 80.000
1     QUAD4 COMPOSITE TUBE                                                   MARCH  23, 1989   RELEASE  1988  CDC    PAGE    13
      SYMMETRIC LAYUP [45/-45/0/90]S
0     TUBE UNDER CONSTANT PRESSURE P
0                                              S O R T E D   B U L K   D A T A   E C H O
     CARD
     COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
      273-        GRID    141     1       50.000  45.000  80.000
      274-        GRID    142     1       50.000  337.500 80.000
      275-        GRID    143     1       50.000  22.500  80.000
      276-        GRID    144     1       50.000  0.000   80.000
      277-        MAT8    1       73.8 E+33.75 E+30.4     1.74 E+3                        +MA1
      278-        +MA1                            1680.   -229.0  20.9    -137.0  82.9
      279-        PCOMP   2       -0.96           10000.0 HILL                    SYM     +PC1
      280-        +PC1    1       .24     45.0    YES                     -45.0   YES     +PC2
      281-        +PC2                    0.0     YES                     90.0    YES
      282-        PLOAD4  1       1       10.5                            THRU    128
      283-        SPC1    1       3       1       9       16      24
      284-        SPC1    1       6       1       THRU    144
      285-        SPC1    1       145     9       24      136     137
      236-        SPC1    1       245     1       16      129     144
                  ENDDATA
```

SYMMETRIC LAYUP [45/-45/0/90]S SUBCASE 1
0 TUBE UNDER CONSTANT PRESSURE P

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
29	G	3.467347E-01	3.438213E-01	-3.005464E-02	-4.671168E-04	2.562122E-04	.0
45	G	3.470449E-01	3.449179E-01	-6.224011E-02	-7.687557E-04	2.196042E-04	.0
61	G	3.470868E-01	3.455627E-01	-9.453406E-02	3.007555E-04	5.882263E-04	.0
77	G	3.485623E-01	3.478297E-01	-1.268109E-01	-2.582375E-04	-6.487657E-04	.0

F O R C E S   I N   L A Y E R E D   C O M P O S I T E   E L E M E N T S   (Q U A D 4)

ELEMENT	- MEMBRANE FORCES -			- BENDING MOMENTS -			- TRANSVERSE SHEAR FORCES -	
ID	FX	FY	FXY	MX	MY	MXY	VX	VY
8	-3.23585E-01	5.13704E+02	-2.78695E+00	-9.55642E-01	-5.03415E-01	-3.47035E-01	2.50866E-01	7.98488E-02
24	-1.76318E+00	5.15419E+02	-4.17148E+00	1.67649E-01	1.12397E-01	1.26337E-01	7.1[illegible]E-01	2.44435E-01

S T R E S S E S I N L A Y E R E D C O M P O S I T E E L E M E N T S (Q U A D 4)

ELEMENT ID	PLY ID	STRESSES IN FIBER AND MATRIX DIRECTIONS NORMAL-1	NORMAL-2	SHEAR-12	DIRECT FIBER FAILURE INDEX		INTER-LAMINAR STRESSES SHEAR-1Z	SHEAR-2Z	SHEAR BOND FAILURE INDEX	MAXIMUM INDEX
8	1	2.42459E+02	1.74821E+01	2.27715E+01	.724		6.06611E-02	2.87590E-02	.000	
	2	2.44256E+02	1.71668E+01	-2.27482E+01	.771		1.16676E-01	4.93811E-02	.000	
	3	-2.26804E+02	3.21873E+01	-2.57793E-01	3.492	*	2.18566E-01	5.14888E-02	.000	
	4	7.25222E+02	2.61147E+00	2.49960E-01	.281		2.24292E-01	6.58359E-02	.000	
	5	7.25242E+02	[illegible]	2.42128E-01	.282		2.18566E-01	5.14888E-02	.000	
	6	-2.23857E+02	3.22497E+01	-2.34295E-01	3.474	*	1.16676E-01	4.93811E-02	.000	
	7	2.55967E+02	1.73650E+01	-2.26323E+01	.787		6.06611E-02	2.87590E-02	.000	
	8	2.47150E+02	1.76934E+01	2.26051E+01	.811		4.65862E-16	3.93821E-15	.000	
				HILL FAILURE THEORY WAS USED FOR THIS ELEMENT.						3.492 *
24	1	2.42962E+02	1.76850E+01	2.28173E+01	.611		1.92790E-01	8.80378E-02	.000	
	2	2.57771E+02	1.72176E+01	-2.28209E+01	.776		3.30459E-01	1.50922E-01	.000	
	3	-2.27978E+02	3.23287E+01	-3.61798E-01	3.522	*	6.19111E-01	1.57619E-01	.000	
	4	7.28287E+02	2.55879E+00	3.66112E-01	.292		6.24000E-01	2.01551E-01	.000	
	5	7.23283E+02	2.55110E+00	3.79426E-01	.282		6.19111E-01	1.57619E-01	.000	
	6	-2.28313E+02	3.23135E+01	-3.74741E-01	3.525	*	3.30459E-01	1.50922E-01	.000	
	7	2.57837E+02	1.71760E+01	-2.28380E+01	.773		1.92790E-01	8.80378E-02	.000	
	8	2.41750E+02	1.76676E+01	2.28421E+01	.810		1.31734E-15	1.28313E-15	.000	
				HILL FAILURE THEORY WAS USED FOR THIS ELEMENT.						3.525 *

PROBLEM #12

```
ID UAI/NASTRAN PROBLEM 6
SOL 1,0
APP DISP
TIME 30
CEND
  COMPOS *** UAI *** QUAD4 4-NODE SHELL ROOF TEST                        MARCH  23, 1989   RELEASE  1988  CDC    PAGE     2
  LAMINATED  COMPOSITE SHELL

                                      C A S E    C O N T R O L    D E C K    E C H O
               CARD
               COUNT
                 1      TITLE = COMPOS *** UAI *** QUAD4 4-NODE SHELL ROOF TEST
                 2      SUBTITLE = LAMINATED  COMPOSITE SHELL
                 3      $
                 4      $
                 5      $    MODEL: LAMINATED COMPOSITE SHELL ROOF MODEL.
                 6      $           SYMMETRIC ANGLE PLY LAYUP
                 7      $           [ 45/-45/15/-15/-15/15/-45/45 ]
                 8      $
                 9      $
                10      $      * * COMPARISION OF T1 DEFLECTION AT GRIDS  *
                11      $      * * 34,35,36,43,44,45 * *
                12      $
                13      $             UAI/NASTRAN        MSC/NASTRAN
                14      $      ---------------------------------------------
                15      $ GRID 34     -1.1187            -1.0662
                16      $ GRID 35     -1.4140            -1.3441
                17      $ GRID 36     -1.6911            -1.6074
                18      $ GRID 43     -1.3918            -1.3267
                19      $ GRID 44     -1.7590            -1.6739
                20      $ GRID 45     -2.1002            -2.0079
                21      $
                22      $
                23      SPC = 1
                24      LOAD = 1
                25      DISP = ALL
                26      OLOAD(PRINT,PUNCH) = ALL
                27      BEGIN BULK
  COMPOS *** UAI *** QUAD4 4-NODE SHELL ROOF TEST                        MARCH  23, 1989   RELEASE  1988  CDC    PAGE     3
  LAMINATED  COMPOSITE SHELL

*** USER INFORMATION MESSAGE 207.  BULK DATA NOT SORTED, XSORT WILL RE-ORDER DECK.
  COMPOS *** UAI *** QUAD4 4-NODE SHELL ROOF TEST                        MARCH  23, 1989   RELEASE  1988  CDC    PAGE     4
  LAMINATED  COMPOSITE SHELL

                                      S O R T E D    B U L K    D A T A    E C H O
               CARD
               COUNT    ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
                 1-     CORD2C  1               0.0     0.0     0.0     -1.0    0.0     0.0     +COR1001
                 2-     +COR1001 0.0    0.0     1.0
                 3-     CORD2R  2       0       0.0     0.0     0.0     0.0     0.0     1.0     +C2
                 4-     +C2     1.0     0.0     0.0
                 5-     CORD2R  3       0       0.0     0.0     0.0     0.0     0.0     1.0     +C3
                 6-     +C3     1.0     0.0     0.0
                 7-     CORD2R  5       1       25.0    0.0     0.0     20.0    0.0     0.0     +HI2
                 8-     +HI2    20.0    5.0     0.0
                 9-     CQUAD4  2       1       1       2       11      10      5
                10-     CQUAD4  3       1       2       3       12      11      5
                11-     CQUAD4  4       1       3       4       13      12      5
                12-     CQUAD4  5       1       4       5       14      13      5
                13-     CQUAD4  6       1       5       6       15      14      5
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14-	CQUAD4	7	1	6	7	16	15	5
15-	CQUAD4	8	1	7	8	17	16	5
16-	CQUAD4	9	1	8	9	18	17	5
17-	CQUAD4	10	1	10	11	20	19	5
18-	CQUAD4	11	1	11	12	21	20	5
19-	CQUAD4	12	1	12	13	22	21	5
20-	CQUAD4	13	1	13	14	23	22	5
21-	CQUAD4	14	1	14	15	24	23	5
22-	CQUAD4	15	1	15	16	25	24	5
23-	CQUAD4	16	1	16	17	26	25	5
24-	CQUAD4	17	1	17	18	27	26	5
25-	CQUAD4	18	1	19	20	29	28	5
26-	CQUAD4	19	1	20	21	30	29	5
27-	CQUAD4	20	1	21	22	31	30	5
28-	CQUAD4	21	1	22	23	32	31	5
29-	CQUAD4	22	1	23	24	33	32	5
30-	CQUAD4	23	1	24	25	34	33	5
31-	CQUAD4	24	1	25	26	35	34	5
32-	CQUAD4	25	1	26	27	36	35	5
33-	CQUAD4	26	1	28	29	38	37	5
34-	CQUAD4	27	1	29	30	39	38	5

S O R T E D B U L K D A T A E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10.++
35-	CQUAD4	28	1	30	31	40	39	5		
36-	CQUAD4	29	1	31	32	41	40	5		
37-	CQUAD4	30	1	32	33	42	41	5		
38-	CQUAD4	31	1	33	34	43	42	5		
39-	CQUAD4	32	1	34	35	44	43	5		
40-	CQUAD4	33	1	35	36	45	44	5		
41-	CQUAD4	34	1	37	38	47	46	5		
42-	CQUAD4	35	1	38	39	48	47	5		
43-	CQUAD4	36	1	39	40	49	48	5		
44-	CQUAD4	37	1	40	41	50	49	5		
45-	CQUAD4	38	1	41	42	51	50	5		
46-	CQUAD4	39	1	42	43	52	51	5		
47-	CQUAD4	40	1	43	44	53	52	5		
48-	CQUAD4	41	1	44	45	54	53	5		
49-	CQUAD4	42	1	46	47	56	55	5		
50-	CQUAD4	43	1	47	48	57	56	5		
51-	CQUAD4	44	1	48	49	58	57	5		
52-	CQUAD4	45	1	49	50	59	58	5		
53-	CQUAD4	46	1	50	51	60	59	5		
54-	CQUAD4	47	1	51	52	61	60	5		
55-	CQUAD4	48	1	52	53	62	61	5		
56-	CQUAD4	49	1	53	54	63	62	5		
57-	CQUAD4	50	1	55	56	65	64	5		
58-	CQUAD4	51	1	56	57	66	65	5		
59-	CQUAD4	52	1	57	58	67	66	5		
60-	CQUAD4	53	1	58	59	68	67	5		
61-	CQUAD4	54	1	59	60	69	68	5		
62-	CQUAD4	55	1	60	61	70	69	5		
63-	CQUAD4	56	1	61	62	71	70	5		
64-	CQUAD4	57	1	62	63	72	71	5		
65-	CQUAD4	58	1	64	65	74	73	5		
66-	CQUAD4	59	1	65	66	75	74	5		
67-	CQUAD4	60	1	66	67	76	75	5		
68-	CQUAD4	61	1	67	68	77	76	5		

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
69-	CQUAD4	62	1	68	69	78	77	5		
70-	CQUAD4	63	1	69	70	79	78	5		
71-	CQUAD4	64	1	70	71	80	79	5		
72-	CQUAD4	65	1	71	72	81	80	5		
73-	CRIGD1	1	81	5001						
74-	GRID	1	1	25.000	0.000	0.000	1			
75-	GRID	2	1	25.000	5.000	0.000	1			
76-	GRID	3	1	25.000	10.000	0.000	1			
77-	GRID	4	1	25.000	15.000	0.000	1			
78-	GRID	5	1	25.000	20.000	0.000	1			
79-	GRID	6	1	25.000	25.000	0.000	1			
80-	GRID	7	1	25.000	30.000	0.000	1			
81-	GRID	8	1	25.000	35.000	0.000	1			
82-	GRID	9	1	25.000	40.000	0.000	1			
83-	GRID	10	1	25.000	0.000	3.125	1			
84-	GRID	11	1	25.000	5.000	3.125	1			
85-	GRID	12	1	25.000	10.000	3.125	1			
86-	GRID	13	1	25.000	15.000	3.125	1			
87-	GRID	14	1	25.000	20.000	3.125	1			
88-	GRID	15	1	25.000	25.000	3.125	1			
89-	GRID	16	1	25.000	30.000	3.125	1			
90-	GRID	17	1	25.000	35.000	3.125	1			
91-	GRID	18	1	25.000	40.000	3.125	1			
92-	GRID	19	1	25.000	0.000	6.250	1			
93-	GRID	20	1	25.000	5.000	6.250	1			
94-	GRID	21	1	25.000	10.000	6.250	1			
95-	GRID	22	1	25.000	15.000	6.250	1			
96-	GRID	23	1	25.000	20.000	6.250	1			
97-	GRID	24	1	25.000	25.000	6.250	1			
98-	GRID	25	1	25.000	30.000	6.250	1			
99-	GRID	26	1	25.000	35.000	6.250	1			
100-	GRID	27	1	25.000	40.000	6.250	1			
101-	GRID	28	1	25.000	0.000	9.375	1			
102-	GRID	29	1	25.000	5.000	9.375	1			

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
103-	GRID	30	1	25.000	10.000	9.375	1			
104-	GRID	31	1	25.000	15.000	9.375	1			
105-	GRID	32	1	25.000	20.000	9.375	1			
106-	GRID	33	1	25.000	25.000	9.375	1			
107-	GRID	34	1	25.000	30.000	9.375	1			
108-	GRID	35	1	25.000	35.000	9.375	1			
109-	GRID	36	1	25.000	40.000	9.375	1			
110-	GRID	37	1	25.000	0.000	12.500	1			
111-	GRID	38	1	25.000	5.000	12.500	1			
112-	GRID	39	1	25.000	10.000	12.500	1			
113-	GRID	40	1	25.000	15.000	12.500	1			
114-	GRID	41	1	25.000	20.000	12.500	1			
115-	GRID	42	1	25.000	25.000	12.500	1			
116-	GRID	43	1	25.000	30.000	12.500	1			
117-	GRID	44	1	25.000	35.000	12.500	1			
118-	GRID	45	1	25.000	40.000	12.500	1			
119-	GRID	46	1	25.000	0.000	15.625	1			
120-	GRID	47	1	25.000	5.000	15.625	1			
121-	GRID	48	1	25.000	10.000	15.625	1			

```
 122-        GRID    49      1       25.000  15.000  15.625  1
 123-        GRID    50      1       25.000  20.000  15.625  1
 124-        GRID    51      1       25.000  25.000  15.625  1
 125-        GRID    52      1       25.000  30.000  15.625  1
 126-        GRID    53      1       25.000  35.000  15.625  1
 127-        GRID    54      1       25.000  40.000  15.625  1
 128-        GRID    55      1       25.000  0.000   18.750  1
 129-        GRID    56      1       25.000  5.000   18.750  1
 130-        GRID    57      1       25.000  10.000  18.750  1
 131-        GRID    58      1       25.000  15.000  18.750  1
 132-        GRID    59      1       25.000  20.000  18.750  1
 133-        GRID    60      1       25.000  25.000  18.750  1
 134-        GRID    61      1       25.000  30.000  18.750  1
 135-        GRID    62      1       25.000  35.000  18.750  1
 136-        GRID    63      1       25.000  40.000  18.750  1
```


S O R T E D   B U L K   D A T A   E C H O

```
CARD
COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
 137-        GRID    64      1       25.000  0.000   21.875  1
 138-        GRID    65      1       25.000  5.000   21.875  1
 139-        GRID    66      1       25.000  10.000  21.875  1
 140-        GRID    67      1       25.000  15.000  21.875  1
 141-        GRID    68      1       25.000  20.000  21.875  1
 142-        GRID    69      1       25.000  25.000  21.875  1
 143-        GRID    70      1       25.000  30.000  21.875  1
 144-        GRID    71      1       25.000  35.000  21.875  1
 145-        GRID    72      1       25.000  46.600  21.875  1
 146-        GRID    73      1       25.000  0.000   25.000  1
 147-        GRID    74      1       25.000  5.000   25.000  1
 148-        GRID    75      1       25.000  10.000  25.000  1
 149-        GRID    76      1       25.000  15.000  25.000  1
 150-        GRID    77      1       25.000  20.000  25.000  1
 151-        GRID    78      1       25.000  25.000  25.000  1
 152-        GRID    79      1       25.000  30.000  25.000  1
 153-        GRID    80      1       25.000  35.000  25.000  1
 154-        GRID    81      1       25.000  40.000  25.000  1
 155-        GRID    5001    1       25.0    40.0    25.0    3
 156-        MAT8    1       20.0 E+70.5 E+070.25    0.25 E+70.25 E+70.25 E+7
 157-        PCOMP   1                                                       +PC1
 158-        +PC1    1       .03125  45.0    YES                     -45.0   YES     +PC2
 159-        +PC2    1       .03125  15.0    YES                     -15.0   YES     +PC3
 160-        +PC3    1       .03125  -15.0   YES                     15.0    YES     +PC4
 161-        +PC4    1       .03125  -45.0   YES                     45.0    YES
 162-        PLOAD4  1       2       90.0                            THRU    65      +PL1
 163-        +PL1    2       0.0     0.0     -1.0
 164-        SPC1    1       4       1       9       10      18      19      27      +MIN
 165-        +MIN    28      36      37      45      46      54      55      63      +MIN1
 166-        +MIN1   64      72
 167-        SPC1    1       12      1       2       3       4       5       6       +SP10001
 168-        +SP100017       8       9
 169-        SPC1    1       26      1       10      19      28      37      46      +SP10005
 170-        +SP1000555      64      73
```


S O R T E D   B U L K   D A T A   E C H O

```
CARD
COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
 171-        SPC1    1       35      73      74      75      76      77      78      +SP10003
 172-        +SP1000379      80      81
             ENDDATA
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	.0	.0	2.231236E-02	.0	6.817505E-03	.0
2	G	.0	.0	3.002084E-02	5.887511E-02	1.468109E-05	1.755119E-03
3	G	.0	.0	3.261839E-02	1.100732E-01	-1.595813E-02	2.568997E-03
4	G	.0	.0	3.381676E-02	1.481686E-01	-3.952171E-02	3.449476E-03
5	G	.0	.0	2.946481E-02	1.687044E-01	-6.872395E-02	3.961035E-03
6	G	.0	.0	1.419531E-02	1.652240E-01	-1.018398E-01	4.421340E-03
7	G	.0	.0	-1.834989E-02	1.581470E-01	-1.367115E-01	4.192573E-03
8	G	.0	.0	-7.528201E-02	1.244091E-01	-1.703734E-01	4.610266E-03
9	G	.0	.0	-1.644548E-01	.0	-1.960604E-01	2.800160E-03
10	G	3.325734E-02	.0	2.872432E-02	.0	6.762861E-03	.0
11	G	1.589026E-02	-2.292669E-03	2.384693E-02	6.782956E-02	3.837667E-03	1.570089E-02
12	G	-3.112297E-02	-1.760152E-03	3.224522E-02	1.033408E-01	-9.959379E-03	2.724639E-02
13	G	-1.010663E-01	3.890004E-03	3.326729E-02	1.355058E-01	-3.889546E-02	3.683240E-02
14	G	-1.894841E-01	1.645084E-02	2.383363E-02	1.549632E-01	-5.761424E-02	4.454504E-02
15	G	-2.910272E-01	3.726333E-02	1.371384E-02	1.638041E-01	-8.019250E-02	4.971170E-02
16	G	-3.988076E-01	6.708948E-02	-1.821144E-02	1.573638E-01	-1.204452E-01	5.184087E-02
17	G	-5.046351E-01	1.093398E-01	-7.362047E-02	1.519317E-01	-1.525552E-01	5.050477E-02
18	G	-6.003962E-01	1.528466E-01	-1.592124E-01	.0	-1.770048E-01	4.658273E-02
19	G	6.301904E-02	.0	2.801017E-02	.0	4.977118E-03	.0
20	G	3.125473E-02	-4.038726E-03	2.389788E-02	7.203086E-02	1.316321E-03	2.855850E-02
21	G	-3.705896E-02	-2.761586E-03	3.078766E-02	1.166358E-01	-1.038321E-02	5.176908E-02
22	G	-1.912060E-01	8.340085E-03	3.128653E-02	1.454863E-01	-2.932057E-02	7.075454E-02
23	G	-3.609312E-01	3.278882E-02	2.665387E-02	1.608323E-01	-5.323294E-02	8.531525E-02
24	G	-5.544508E-01	7.[illegible]70E-02	1.210807E-02	1.609143E-01	-8.015075E-02	9.463006E-02
25	G	-7.573215E-01	1.303881E-01	-1.778819E-02	1.516218E-01	-1.082323E-01	9.805495E-02
26	G	-9.570887E-01	2.045640E-01	-6.868640E-02	1.333956E-01	-1.360885E-01	9.628893E-02
27	G	-1.1[illegible]0E+00	2.940887E-01	-1.460617E-01	.0	-1.586747E-01	9.264753E-02
28	G	8.302374E-02	.0	2.612841E-02	.0	1.281244E-05	.0
29	G	3.963067E-02	-5.099369E-03	2.676805E-02	8.743575E-02	5.296311E-04	3.931383E-02
30	G	-8.435201E-02	-2.792843E-03	2.798218E-02	9.962546E-02	-1.002320E-02	7.389390E-02
31	G	-2.746829E-01	1.336716E-02	2.780828E-02	1.154709E-01	-2.578196E-02	1.004083E-01
32	G	-5.153260E-01	4.842272E-02	2.307334E-02	1.218567E-01	-4.596176E-02	1.207275E-01
33	G	-7.880352E-01	1.057852E-01	9.747583E-03	1.205370E-01	-6.877118E-02	1.332012E-01
34	G	-1.073541E+00	1.870450E-01	-1.569264E-02	1.143494E-01	-9.281759E-02	1.379633E-01

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

POINT ID	TYPE	T1	T2	T3	R1	R2	R3
35	G	-1.354492E+00	2.920057E-01	-6.997532E-02	1.153672E-01	-1.176982E-01	1.371895E-01
36	G	-1.621261E+00	4.191498E-01	-1.288312E-01	.0	-1.375426E-01	1.354583E-01
37	G	9.528611E-02	.0	2.305572E-02	.0	6.039361E-04	.0
38	G	4.169106E-02	-5.509154E-03	2.340316E-02	6.534988E-02	-2.263016E-03	4.809104E-02
39	G	-1.105576E-01	-1.957446E-03	2.399369E-02	1.956236E-01	-8.933205E-03	9.002047E-02
40	G	-3.459285E-01	1.863788E-02	2.326388E-02	1.211084E-01	-2.116810E-02	1.245331E-01
41	G	-6.442223E-01	6.256879E-02	1.876561E-02	1.264267E-01	-3.695541E-02	1.497939E-01
42	G	-9.821585E-01	1.340743E-01	7.329960E-03	1.212973E-01	-5.521942E-02	1.652686E-01
43	G	-1.336338E+00	2.351901E-01	-1.466919E-02	1.113931E-01	-7.499070E-02	1.718182E-01
44	G	-1.687574E+00	3.659161E-01	-5.114555E-02	9.453569E-02	-9.526951E-02	1.726276E-01
45	G	-2.029702E+00	5.248147E-01	-1.061536E-01	.0	-1.131190E-01	1.734600E-01
46	G	9.858108E-02	.0	1.873998E-02	.0	-6.339950E-03	.0
47	G	3.958965E-02	-5.376200E-03	1.889673E-02	9.985430E-02	-5.226975E-04	5.383342E-02
48	G	-1.330199E-01	-5.411460E-04	1.895501E-02	7.687086E-02	-7.016597E-03	1.026300E-01
49	G	-4.019700E-01	2.364893E-02	1.793490E-02	7.516055E-02	-1.558065E-02	1.426298E-01
50	G	-7.442126E-01	7.448625E-02	1.409245E-02	7.085969E-02	-2.727956E-02	1.722287E-01
51	G	-1.133080E+00	1.569567E-01	5.082104E-03	6.637885E-02	-4.114150E-02	1.905354E-01
52	G	-1.542078E+00	2.735546E-01	-1.185245E-02	6.337582E-02	-5.632919E-02	1.989912E-01
53	G	-1.950465E+00	4.245314E-01	-3.966756E-02	7.869894E-02	-7.308949E-02	2.015551E-01
54	G	-2.348443E+00	6.086016E-01	-8.149300E-02	.0	-8.552130E-02	2.043495E-01
55	G	9.925527E-02	.0	1.303841E-02	.0	1.192696E-03	.0
56	G	3.436526E-02	-4.902545E-03	1.328109E-02	3.806582E-02	-4.634634E-03	5.787999E-02
57	G	-1.569353E-01	1.092634E-03	1.367773E-02	9.104075E-02	-5.315245E-03	1.104359E-01
58	G	-4.418881E-01	2.787236E-02	1.211830E-02	1.009372E-01	-1.059203E-02	1.551042E-01
59	G	-8.146890E-01	9.353733E-02	9.305028E-03	1.007360E-01	-1.784360E-02	1.881992E-01
60	G	-1.239991E+00	1.737124E-01	3.110855E-03	9.024327E-02	-2.695793E-02	2.089143E-01
61	G	-1.688882E+00	3.013031E-01	-8.305585E-03	7.466577E-02	-3.728758E-02	2.189563E-01
62	G	-2.139203E+00	4.667825E-01	-2.700414E-02	4.531844E-02	-4.756398E-02	2.229519E-01
63	G	-2.582725E+00	6.691096E-01	-5.506216E-02	.0	-5.917378E-02	2.285320E-01
64	G	8.989964E-02	.0	6.956502E-03	.0	-1.643950E-02	.0
65	G	2.752476E-02	-4.270855E-03	6.925065E-03	1.048371E-01	9.207647E-04	5.791431E-02
66	G	-1.618395E-01	2.501839E-03	6.714253E-03	4.180168E-02	-1.920723E-03	1.143999E-01
67	G	-4.644474E-01	3.077636E-02	6.190041E-03	1.775697E-02	-3.827643E-03	1.619098E-01
68	G	-8.549791E-01	8.319614E-02	4.614648E-03	1.775469E-03	-7.423402E-03	1.976275E-01

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
69	G	-1.302510E+00	1.836416E-01	1.462140E-03	-5.660198E-03	-1.232690E-02	2.201447E-01
[illegible]	G	-1.776588E+00	3.179508E-01	-4.267257E-03	3.084882E-04	-1.829488E-02	2.316046E-01
[illegible]	G	-2.254081E+00	4.822265E-01	-1.358495E-02	2.996896E-02	-2.613048E-02	2.367952E-01
[illegible]	G	-2.724831E+00	7.856920E-01	-2.778339E-02	.0	-2.787699E-02	2.429224E-01
[illegible]	G	9.319466E-02	.0	.0	-5.776193E-01	.0	.0
[illegible]	G	2.635430E-02	-4.094534E-03	.0	6.521527E-02	.0	5.899722E-02
[illegible]	G	-1.651896E-01	2.239898E-03	.0	8.793802E-02	.0	1.133334E-01
[illegible]	G	-4.702460E-01	3.182782E-02	.0	1.860875E-01	.0	1.631115E-01
[illegible]	G	-8.663865E-01	9.111498E-02	.0	1.015210E-01	.0	2.002252E-01
[illegible]	G	-1.321572E+00	1.871915E-01	.0	8.902934E-02	.0	2.240963E-01
[illegible]	G	-1.865095E+00	3.214278E-01	.0	4.606501E-02	.0	2.365639E-01
80	G	-2.295017E+00	5.067200E-01	.0	1.256455E-02	.0	2.437393E-01
[illegible]	G	-2.781309E+00	7.183357E-01	.0	-1.952295E-01	.0	2.500039E-01
[illegible]	[illegible]	.0	-1.237476E+00	-2.592376E+00	-2.500839E-01	-1.254511E-01	-1.495545E-01

L O A D   V E C T O R

POINT ID	TYPE	T1	T2	T3	R1	R2	R3
[illegible]	[illegible]	-1.[illegible]E+02	.0	.0	.0	.0	.0
[illegible]	[illegible]	-2.059317E+02	2.673056E+01	.0	.0	.0	.0
[illegible]	[illegible]	-2.620374E+02	5.325769E+01	.0	.0	.0	.0
[illegible]	[illegible]	-2.962483E+02	7.937958E+01	.0	.0	.0	.0
[illegible]	[illegible]	-2.882026E+02	1.048972E+02	.0	.0	.0	.0
[illegible]	[illegible]	-2.779635E+02	1.296105E+02	.0	.0	.0	.0
[illegible]	[illegible]	[illegible]	1.533494E+02	.0	.0	.0	.0
[illegible]	[illegible]	-2.512330E+02	1.759152E+02	.0	.0	.0	.0
[illegible]	[illegible]	-1.174735E+02	9.857110E+01	.0	.0	.0	.0
[illegible]	[illegible]	-3.066988E+02	.0	.0	.0	.0	.0
[illegible]	[illegible]	-6.110635E+02	5.346113E+01	.0	.0	.0	.0
[illegible]	[illegible]	-6.040787E+02	1.065154E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.924966E+02	1.587590E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.784052E+02	2.097943E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.559271E+02	2.592330E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.318179E+02	3.066988E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.024659E+02	3.518304E+02	.0	.0	.0	.0
[illegible]	[illegible]	-2.349449E+02	1.971422E+02	.0	.0	.0	.0
[illegible]	[illegible]	-3.066988E+02	.0	.0	.0	.0	.0
[illegible]	[illegible]	-6.110635E+02	5.346113E+01	.0	.0	.0	.0
[illegible]	[illegible]	-6.040787E+02	1.065154E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.924966E+02	1.587590E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.784052E+02	2.097943E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.559271E+02	2.592330E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.318179E+02	3.066988E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.024659E+02	3.518304E+02	.0	.0	.0	.0
[illegible]	[illegible]	-2.349445E+02	1.971422E+02	.0	.0	.0	.0
[illegible]	[illegible]	-3.066988E+02	.0	.0	.0	.0	.0
[illegible]	[illegible]	-6.110635E+02	5.346113E+01	.0	.0	.0	.0
[illegible]	[illegible]	-6.040787E+02	1.065154E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.924966E+02	1.587590E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.784052E+02	2.097943E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.559271E+02	2.592330E+02	.0	.0	.0	.0
[illegible]	[illegible]	-5.318179E+02	3.066988E+02	.0	.0	.0	.0

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
35	G	-5.8246590E+02	3.5183084E+02	.0	.0	.0	.0
36	G	-2.3494439E+02	1.9714228E+02	.0	.0	.0	.0
37	G	-3.0669988E+02	.0	.0	.0	.0	.0
38	G	-6.1106135E+02	5.3461113E+01	.0	.0	.0	.0
39	G	-6.0440787E+02	1.0651540E+02	.0	.0	.0	.0
40	G	-5.9249668E+02	1.5875900E+02	.0	.0	.0	.0
41	G	-5.7640528E+02	2.0979430E+02	.0	.0	.0	.0
42	G	-5.5592771E+02	2.5923390E+02	.0	.0	.0	.0
43	G	-5.3121779E+02	3.0669885E+02	.0	.0	.0	.0
44	G	-5.8246590E+02	3.5183084E+02	.0	.0	.0	.0
45	G	-2.3494439E+02	1.9714228E+02	.0	.0	.0	.0
46	G	-3.0669988E+02	.0	.0	.0	.0	.0
47	G	-6.1106135E+02	5.3461113E+01	.0	.0	.0	.0
48	G	-6.0440787E+02	1.0651540E+02	.0	.0	.0	.0
49	G	-5.9249668E+02	1.5875900E+02	.0	.0	.0	.0
50	G	-5.7640528E+02	2.0979430E+02	.0	.0	.0	.0
51	G	-5.5592771E+02	2.5923390E+02	.0	.0	.0	.0
52	G	-5.3121779E+02	3.0669885E+02	.0	.0	.0	.0
53	G	-5.8246590E+02	3.5183084E+02	.0	.0	.0	.0
54	G	-2.3494439E+02	1.9714228E+02	.0	.0	.0	.0
55	G	-3.0669988E+02	.0	.0	.0	.0	.0
56	G	-6.1106135E+02	5.3461113E+01	.0	.0	.0	.0
57	G	-6.0440787E+02	1.0651540E+02	.0	.0	.0	.0
58	G	-5.9249668E+02	1.5875900E+02	.0	.0	.0	.0
59	G	-5.7640528E+02	2.0979430E+02	.0	.0	.0	.0
60	G	-5.5592771E+02	2.5923390E+02	.0	.0	.0	.0
61	G	-5.3121779E+02	3.0669885E+02	.0	.0	.0	.0
62	G	-5.8246590E+02	3.5183084E+02	.0	.0	.0	.0
63	G	-2.3494439E+02	1.9714228E+02	.0	.0	.0	.0
64	G	-3.0669988E+02	.0	.0	.0	.0	.0
65	G	-6.1106135E+02	5.3461113E+01	.0	.0	.0	.0
66	G	-6.0440787E+02	1.0651540E+02	.0	.0	.0	.0
67	G	-5.9249668E+02	1.5875900E+02	.0	.0	.0	.0
68	G	-5.7640528E+02	2.0979430E+02	.0	.0	.0	.0

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
69	G	-5.559271E+02	2.592330E+02	.0	.0	.0	.0
70	G	-5.312179E+02	3.066988E+02	.0	.0	.0	.0
71	G	-5.024659E+02	3.518304E+02	.0	.0	.0	.0
72	G	-2.349443E+02	1.971422E 02	.0	.0	.0	.0
73	G	-1.533494E+02	.0	.0	.0	.0	.0
74	G	-3.055017E+02	2.673056E+01	.0	.0	.0	.0
75	G	-3.020394E+02	5.325769E+01	.0	.0	.0	.0
76	G	-2.962483E+02	7.937950E+01	.0	.0	.0	.0
77	G	-2.882026E+02	1.048972E+02	.0	.0	.0	.0
78	G	-2.779635E+02	1.296165E+02	.0	.0	.0	.0
79	G	-2.656030E+02	1.533494E+02	.0	.0	.0	.0
80	G	-2.512230E+02	1.759152E+02	.0	.0	.0	.0
81	G	-1.174725E+02	9.857110E+01	.0	.0	.0	.0

```
                    N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

     ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
     APP DISPLACEMENT
     SOL 1,0
     TIME 10
     CEND

                              C A S E   C O N T R O L   D E C K   E C H O
  CARD
  COUNT
   1        TITLE = PROBLEM 13 CASE 1 INPLANE LOADING
   2        LOAD = 1
   3        SPC  = 1
   4        OUTPUT
   5           OLOAD=ALL
   6           STRESS=ALL
   7           DISPLACEMENTS=ALL
   8           STRAIN=ALL
   9        BEGIN BULK
     1-          CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
     2-          +XYP    1.0     0.0     1.0
     3-          CQUAD4  1       1       1       2       8       7       1
     4-          CQUAD4  2       1       2       3       9       8       1
     5-          CQUAD4  3       1       3       4       10      9       1
     6-          CQUAD4  4       1       4       5       11      10      1
     7-          CQUAD4  5       1       5       6       12      11      1
     8-          CQUAD4  6       1       7       8       14      13      1
     9-          CQUAD4  7       1       8       9       15      14      1
    10-          CQUAD4  8       1       9       10      16      15      1
    11-          CQUAD4  9       1       10      11      17      16      1
    12-          CQUAD4  10      1       11      12      18      17      1
    13-          CQUAD4  11      1       13      14      20      19      1
    14-          CQUAD4  12      1       14      15      21      20      1
    15-          CQUAD4  13      1       15      16      22      21      1
    16-          CQUAD4  14      1       16      17      23      22      1
    17-          CQUAD4  15      1       17      18      24      23      1
    18-          CQUAD4  16      1       19      20      26      25      1
    19-          CQUAD4  17      1       20      21      27      26      1
    20-          CQUAD4  18      1       21      22      28      27      1
    21-          CQUAD4  19      1       22      23      29      28      1
    22-          CQUAD4  20      1       23      24      30      29      1
    23-          CQUAD4  21      1       25      26      32      31      1
    24-          CQUAD4  22      1       26      27      33      32      1
    25-          CQUAD4  23      1       27      28      34      33      1
    26-          CQUAD4  24      1       28      29      35      34      1
    27-          CQUAD4  25      1       29      30      36      35      1
    28-          FORCE   1       6               -2.0    1.0     0.0     0.0
    29-          FORCE   1       12              -4.0    1.0     0.0     0.0
    30-          FORCE   1       18              -4.0    1.0     0.0     0.0
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FORCE   1       24              -4.0    1.0     0.0     0.0
FORCE   1       30              -4.0    1.0     0.0     0.0
FORCE   1       36              -2.0    1.0     0.0     0.0
GRID    1               0.0     0.0     0.0
GRID    2               3.0     0.0     0.0
GRID    3               6.0     0.0     0.0
GRID    4               9.0     0.0     0.0
GRID    5               12.0    0.0     0.0
GRID    6               15.0    0.0     0.0
GRID    7               0.0     4.0     0.0
GRID    8               3.0     4.0     0.0
GRID    9               6.0     4.0     0.0
GRID    10              9.0     4.0     0.0
GRID    11              12.0    4.0     0.0
GRID    12              15.0    4.0     0.0
GRID    13              0.0     8.0     0.0
GRID    14              3.0     8.0     0.0
GRID    15              6.0     8.0     0.0
GRID    16              9.0     8.0     0.0
GRID    17              12.0    8.0     0.0
GRID    18              15.0    8.0     0.0
GRID    19              0.0     12.0    0.0
GRID    20              3.0     12.0    0.0
GRID    21              6.0     12.0    0.0
GRID    22              9.0     12.0    0.0
GRID    23              12.0    12.0    0.0
GRID    24              15.0    12.0    0.0
GRID    25              0.0     16.0    0.0
GRID    26              3.0     16.0    0.0
GRID    27              6.0     16.0    0.0
GRID    28              9.0     16.0    0.0
GRID    29              12.0    16.0    0.0
GRID    30              15.0    16.0    0.0
GRID    31              0.0     20.0    0.0
GRID    32              3.0     20.0    0.0
GRID    33              6.0     20.0    0.0
GRID    34              9.0     20.0    0.0
GRID    35              12.0    20.0    0.0
GRID    36              15.0    20.0    0.0
MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
PARAM   GRDPNT  0
PCOMP1  1                                       22      .0236   SYM     ABC
+BC     45.     -45.    90.     0.
SPC1    1       6       1       THRU    36
SPC1    1       36      1       THRU    6
SPC1    1       36      6       12      18      24      30      36
SPC1    1       136     1       7       13      19      25      31
SPC1    1       236     31      THRU    36
ENDDATA
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	-4.586931E-06	0.0	-3.739354E-22	1.350191E-22	0.0
2	G	-2.200378E-06	-4.586931E-06	0.0	-2.377961E-21	-1.630386E-22	0.0
3	G	-4.400757E-06	-4.586931E-06	0.0	-3.200120E-21	-2.832612E-22	0.0
4	G	-6.601135E-06	-4.586931E-06	0.0	-2.924989E-21	-4.927746E-22	0.0
5	G	-8.801513E-06	-4.586931E-06	0.0	-1.749883E-21	-6.912656E-22	0.0
6	G	-1.100189E-05	-4.586931E-06	0.0	-2.375740E-22	-6.298611E-22	0.0
7	G	0.0	-3.669544E-06	0.0	-1.472087E-22	2.774235E-21	0.0
8	G	-2.200378E-06	-3.669544E-06	-7.287472E-21	-1.450458E-21	1.688366E-21	0.0
9	G	-4.400757E-06	-3.669544E-06	-1.095683E-20	-2.326285E-21	1.925028E-22	0.0
10	G	-6.601135E-06	-3.669544E-06	-1.044381E-20	-2.380581E-21	-1.288238E-21	0.0
11	G	-8.801513E-06	-3.669544E-06	-6.208032E-21	-1.622087E-21	-2.497168E-21	0.0
12	G	-1.100189E-05	-3.669544E-06	0.0	-3.016316E-22	-2.690360E-21	0.0
13	G	0.0	-2.752158E-06	0.0	-1.581260E-22	3.783715E-21	0.0
14	G	-2.200378E-05	-2.752158E-06	-1.067713E-20	-4.566404E-22	2.795794E-21	0.0
15	G	-4.400757E-06	-2.752158E-06	-1.683721E-20	-8.041368E-22	6.983753E-22	0.0
16	G	-6.601135E-06	-2.752158E-06	-1.660366E-20	-9.408494E-22	-1.586746E-21	0.0
17	G	-8.801513E-06	-2.752158E-06	-1.021450E-20	-7.443478E-22	-3.527765E-21	0.0
18	G	-1.100189E-05	-2.752158E-06	0.0	-2.417337E-22	-4.189631E-21	0.0
19	G	0.0	-1.834772E-06	0.0	-3.906152E-24	3.473266E-21	0.0
20	G	-2.200378E-06	-1.834772E-06	-1.021954E-20	4.793626E-22	2.806174E-21	0.0
21	G	-4.400757E-06	-1.834772E-06	-1.660582E-20	6.688025E-22	8.647538E-22	0.0
22	G	-6.601135E-06	-1.834772E-06	-1.683507E-20	5.326254E-22	-1.420836E-21	0.0
23	G	-8.801513E-06	-1.834772E-06	-1.067168E-20	1.922288E-22	-3.517113E-21	0.0
24	G	-1.100189E-05	-1.834772E-06	0.0	-8.275889E-23	-4.500022E-21	0.0
25	G	0.0	-9.173861E-07	0.0	5.363293E-23	1.973869E-21	0.0
26	G	-2.200378E-06	-9.173861E-07	-6.212500E-21	1.355181E-21	1.777284E-21	0.0
27	G	-4.400757E-06	-9.173861E-07	-1.044628E-20	2.108294E-21	5.667328E-22	0.0
28	G	-6.601135E-06	-9.173861E-07	-1.095559E-20	2.054565E-21	-9.129689E-22	0.0
29	G	-8.801513E-06	-9.173861E-07	-7.282610E-21	1.187933E-21	-2.409765E-21	0.0
30	G	-1.100189E-05	-9.173861E-07	0.0	-9.025533E-23	-3.488668E-21	0.0
31	G	0.0	0.0	0.0	-1.634195E-23	-8.226114E-23	0.0
32	G	-2.200378E-06	0.0	0.0	1.483997E-21	-2.799380E-23	0.0
33	G	-4.400757E-06	0.0	0.0	2.653633E-21	-2.217389E-22	0.0
34	G	-6.601135E-06	0.0	0.0	2.928972E-21	-4.339853E-22	0.0
35	G	-8.801513E-06	0.0	0.0	2.114021E-21	-5.510358E-22	0.0
36	G	-1.100189E-05	0.0	0.0	1.404663E-22	-8.513567E-22	0.0

* * * END OF JOB * * *

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              N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 1
TIME 10
CEND
                                 C A S E   C O N T R O L   D E C K   E C H O

      1      TITLE = PROBLEM 13 CASE 1 INPLANE LOADING
      2      LOAD = 1
      3      SPC  = 1
      4      OUTPUT
      5         OLOAD=ALL
      6         STPESS=ALL
      7         J.SPLACEMENTS=ALL
      8         STRAIN=ALL
      9      BEGIN BULK

     COUNT       .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
        1-       CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
        2-       +XYP    1.0     0.0     1.0
        3-       CQUAD4  1       1       1       2       8       7       1
        4-       CQUAD4  2       1       2       3       9       8       1
        5-       CQUAU4  3       1       3       4       10      9       1
        6-       CQUAD4  4       1       4       5       11      10      1
        7-       CQUAD4  5       1       5       6       12      11      1
        8-       CQUAD4  6       1       7       8       14      13      1
        9-       CQUAD4  7       1       8       9       15      14      1
       10-       CQUAD4  8       1       9       10      16      15      1
       11-       CQUAD4  9       1       10      11      17      16      1
       12-       CQUAD4  10      1       11      12      18      17      1
       13-       CQUAD4  11      1       13      14      20      19      1
       14-       CQUAD4  12      1       14      15      21      20      1
       15-       CQUAD4  13      1       15      16      22      21      1
       16-       CQUAD4  14      1       16      17      23      22      1
       17-       CQUAD4  15      1       17      18      24      23      1
       18-       CQUAD4  16      1       19      20      26      25      1
       19-       CQUAD4  17      1       20      21      27      26      1
       20-       CQUAD4  18      1       21      22      28      27      1
       21-       CQUAD4  19      1       22      23      29      28      1
       22-       CQUAD4  20      1       23      24      30      29      1
       23-       CQUAD4  21      1       25      26      32      31      1
       24-       CQUAD4  22      1       26      27      33      32      1
       25-       CQUAD4  23      1       27      28      34      33      1
       26-       CQUAD4  24      1       28      29      35      34      1
       27-       CQUAD4  25      1       29      30      36      35      1
       28-       FORCE   1       6               -2.0    1.0     0.0     0.0
       29-       FORCE   1       12              -4.0    1.0     0.0     0.0
       30-       FORCE   1       18              -4.0    1.0     0.0     0.0
       31-       FORCE   1       24              -4.0    1.0     0.0     0.0
```

```
FORCE   1       30              -4.0    1.0     0.0     0.0
FORCE   1       36              -2.0    1.0     0.0     0.0
GRID    1               0.0     0.0     0.0
GRID    2               3.0     0.0     0.0
GRID    3               6.0     0.0     0.0
GRID    4               9.0     0.0     0.0
GRID    5               12.0    0.0     0.0
GRID    6               15.0    0.0     0.0
GRID    7               0.0     4.0     0.0
GRID    8               3.0     4.0     0.0
GRID    9               6.0     4.0     0.0
GRID    10              9.0     4.0     0.0
GRID    11              12.0    4.0     0.0
GRID    12              15.0    4.0     0.0
GRID    13              0.0     8.0     0.0
GRID    14              3.0     8.0     0.0
GRID    15              6.0     8.0     0.0
GRID    16              9.0     8.0     0.0
GRID    17              12.0    8.0     0.0
GRID    18              15.0    8.0     0.0
GRID    19              0.0     12.0    0.0
GRID    20              3.0     12.0    0.0
GRID    21              6.0     12.0    0.0
GRID    22              9.0     12.0    0.0
GRID    23              12.0    12.0    0.0
GRID    24              15.0    12.0    0.0
GRID    25              0.0     16.0    0.0
GRID    26              3.0     16.0    0.0
GRID    27              6.0     16.0    0.0
GRID    28              9.0     16.0    0.0
GRID    29              12.0    16.0    0.0
GRID    30              15.0    16.0    0.0
GRID    31              0.0     20.0    0.0
GRID    32              3.0     20.0    0.0
GRID    33              6.0     20.0    0.0
GRID    34              9.0     20.0    0.0
GRID    35              12.0    20.0    0.0
GRID    36              15.0    20.0    0.0
MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
PARAM   GRDPNT  0
PCOMP   1                                                               +KKP
+KKP    22      .0236   45.0    YES     22      .0236   -45.0   YES     +KKQ
+KKQ    22      .0236   90.0    YES     22      .0236   0.0     YES     +KKS
+KKS    22      .0236   0.0     YES     22      .0236   90.0    YES     +KKR
+KKR    22      .0236   -45.0   YES     22      .0236   45.0    YES
SPC1    1       6       1       THRU    36
SPC1    1       36      1       THRU    6
SPC1    1       36      6       12      18      24      30      36
SPC1    1       136     1       7       13      19      25      31
SPC1    1       236     31      THRU    36
ENDDATA
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	-4.586931E-06	0.0	0.0	0.0	0.0
2	G	-2.200378E-06	-4.586931E-06	0.0	0.0	0.0	0.0
3	G	-4.400757E-06	-4.586931E-06	0.0	0.0	0.0	0.0
4	G	-6.601135E-06	-4.586931E-06	0.0	0.0	0.0	0.0
5	G	-8.801513E-06	-4.586931E-06	0.0	0.0	0.0	0.0
6	G	-1.100189E-05	-4.586931E-06	0.0	0.0	0.0	0.0
7	G	0.0	-3.669545E-06	0.0	0.0	0.0	0.0
8	G	-2.200378E-06	-3.669545E-06	0.0	0.0	0.0	0.0
9	G	-4.400757E-06	-3.669545E-06	0.0	0.0	0.0	0.0
10	G	-6.601135E-06	-3.669545E-06	0.0	0.0	0.0	0.0
11	G	-8.801513E-06	-3.669545E-06	0.0	0.0	0.0	0.0
12	G	-1.100189E-05	-3.669545E-06	0.0	0.0	0.0	0.0
13	G	0.0	-2.752158E-06	0.0	0.0	0.0	0.0
14	G	-2.200378E-06	-2.752158E-06	0.0	0.0	0.0	0.0
15	G	-4.400757E-06	-2.752158E-06	0.0	0.0	0.0	0.0
16	G	-6.601135E-06	-2.752158E-06	0.0	0.0	0.0	0.0
17	G	-8.801513E-06	-2.752158E-06	0.0	0.0	0.0	0.0
18	G	-1.100189E-05	-2.752158E-06	0.0	0.0	0.0	0.0
19	G	0.0	-1.834772E-06	0.0	0.0	0.0	0.0
20	G	-2.200378E-06	-1.834772E-06	0.0	0.0	0.0	0.0
21	G	-4.400757E-06	-1.834772E-06	0.0	0.0	0.0	0.0
22	G	-6.601135E-06	-1.834772E-06	0.0	0.0	0.0	0.0
23	G	-8.801513E-06	-1.834772E-06	0.0	0.0	0.0	0.0
24	G	-1.100189E-05	-1.834772E-06	0.0	0.0	0.0	0.0
25	G	0.0	-9.173861E-07	0.0	0.0	0.0	0.0
26	G	-2.200378E-06	-9.173861E-07	0.0	0.0	0.0	0.0
27	G	-4.400757E-06	-9.173861E-07	0.0	0.0	0.0	0.0
28	G	-6.601135E-06	-9.173861E-07	0.0	0.0	0.0	0.0
29	G	-8.801513E-06	-9.173861E-07	0.0	0.0	0.0	0.0
30	G	-1.100189E-05	-9.173861E-07	0.0	0.0	0.0	0.0
31	G	0.0	0.0	0.0	0.0	0.0	0.0
32	G	-2.200378E-06	0.0	0.0	0.0	0.0	0.0
33	G	-4.400757E-06	0.0	0.0	0.0	0.0	0.0
34	G	-6.601135E-06	0.0	0.0	0.0	0.0	0.0
35	G	-8.801513E-06	0.0	0.0	0.0	0.0	0.0
36	G	-1.100189E-05	0.0	0.0	0.0	0.0	0.0

* * * END OF JOB * * *

```
                N A S T R A N    E X E C U T I V E    C O N T R O L    D E C K    E C H O

     ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
     APP DISPLACEMENT
     SOL 1,0
     TIME 10
     CEND

                             C A S E    C O N T R O L    D E C K    E C H O
CARD
COUNT
  1       TITLE = PROBLEM 13  CASE 2   PRESSURE LOAD
  2       LOAD = 1
  3       SPC  = 1
  4       OUTPUT
  5          OLOAD=ALL
  6          STRESS=ALL
  7          DISPLACEMENTS=ALL
  8          STRAIN=ALL
  9       BEGIN BULK
   1-          CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
   2-          +XYP    1.0     0.0     1.0
   3-          CQUAD4  1       1       1       2       8       7       1
   4-          CQUAD4  2       1       2       3       9       8       1
   5-          CQUAD4  3       1       3       4       10      9       1
   6-          CQUAD4  4       1       4       5       11      10      1
   7-          CQUAD4  5       1       5       6       12      11      1
   8-          CQUAD4  6       1       7       8       14      13      1
   9-          CQUAD4  7       1       8       9       15      14      1
  10-          CQUAD4  8       1       9       10      16      15      1
  11-          CQUAD4  9       1       10      11      17      16      1
  12-          CQUAD4  10      1       11      12      18      17      1
  13-          CQUAD4  11      1       13      14      20      19      1
  14-          CQUAD4  12      1       14      15      21      20      1
  15-          CQUAD4  13      1       15      16      22      21      1
  16-          CQUAD4  14      1       16      17      23      22      1
  17-          CQUAD4  15      1       17      18      24      23      1
  18-          CQUAD4  16      1       19      20      26      25      1
  19-          CQUAD4  17      1       20      21      27      26      1
  20-          CQUAD4  18      1       21      22      28      27      1
  21-          CQUAD4  19      1       22      23      29      28      1
  22-          CQUAD4  20      1       23      24      30      29      1
  23-          CQUAD4  21      1       25      26      32      31      1
  24-          CQUAD4  22      1       26      27      33      32      1
  25-          CQUAD4  23      1       27      28      34      33      1
  26-          CQUAD4  24      1       28      29      35      34      1
  27-          CQUAD4  25      1       29      30      36      35      1
  28-          GRID    1               0.0     0.0     0.0
  29-          GRID    2               3.0     0.0     0.0
  30-          GRID    3               6.0     0.0     0.0
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31-     GRID    4               9.0     0.0     0.0
32-     GRID    5               12.0    0.0     0.0
33-     GRID    6               15.0    0.0     0.0
34-     GRID    7               0.0     4.0     0.0
35-     GRID    8               3.0     4.0     0.0
36-     GRID    9               6.0     4.0     0.0
37-     GRID    10              9.0     4.0     0.0
38-     GRID    11              12.0    4.0     0.0
39-     GRID    12              15.0    4.0     0.0
40-     GRID    13              0.0     8.0     0.0
41-     GRID    14              3.0     8.0     0.0
42-     GRID    15              6.0     8.0     0.0
43-     GRID    16              9.0     8.0     0.0
44-     GRID    17              12.0    8.0     0.0
45-     GRID    18              15.0    8.0     0.0
46-     GRID    19              0.0     12.0    0.0
47-     GRID    20              3.0     12.0    0.0
48-     GRID    21              6.0     12.0    0.0
49-     GRID    22              9.0     12.0    0.0
50-     GRID    23              12.0    12.0    0.0
51-     GRID    24              15.0    12.0    0.0
53-     GRID    26              3.0     16.0    0.0
54-     GRID    27              6.0     16.0    0.0
55-     GRID    28              9.0     16.0    0.0
56-     GRID    29              12.0    16.0    0.0
57-     GRID    30              15.0    16.0    0.0
58-     GRID    31              0.0     20.0    0.0
59-     GRID    32              3.0     20.0    0.0
60-     GRID    33              6.0     20.0    0.0
61-     GRID    34              9.0     20.0    0.0
62-     GRID    35              12.0    20.0    0.0
63-     GRID    36              15.0    20.0    0.0
64-     MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
65-     PCOMP1  1                                       22      .0236   SYM     ABC
66-     +BC     45.     -45.    90.     0.
67-     PLOAD2  1       -2.0    1       THRU    25
68-     SPC1    1       6       1       THRU    36
69-     SPC1    1       36      1       THRU    6
70-     SPC1    1       36      6       12      18      24      30      36
71-     SPC1    1       136     1       7       13      19      25      31
72-     SPC1    1       236     31      THRU    36
        ENDDATA
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	-1.778707E-19	0.0	-1.210504E-03	1.323176E-03	0.0
2	G	-6.450161E-20	-2.176825E-19	0.0	-1.668269E-02	-2.098859E-04	0.0
3	G	-1.034476E-19	-2.616967E-19	0.0	-2.286059E-02	1.153546E-04	0.0
4	G	-1.195788E-19	-2.633216E-19	0.0	-2.066866E-02	-5.393717E-04	0.0
5	G	-1.218607E-19	-2.115229E-19	0.0	-1.161163E-02	-8.255243E-04	0.0
6	G	-1.204124E-19	-1.236314E-19	0.0	1.190341E-04	4.164568E-04	0.0
7	G	0.0	-1.481314E-19	0.0	6.716475E-05	2.187735E-02	0.0
8	G	-2.842967E-20	-1.810122E-19	-5.659059E-02	-9.983173E-03	1.411448E-02	0.0
9	G	-8.923749E-20	-2.230359E-19	-8.471517E-02	-1.663885E-02	3.682787E-03	0.0
10	G	-1.576236E-19	-2.311706E-19	-8.078058E-02	-1.696210E-02	-6.537446E-03	0.0
11	G	-2.094548E-19	-1.946830E-19	-4.827733E-02	-1.106920E-02	-1.479205E-02	0.0
12	G	-2.278775E-19	-1.268147E-19	0.0	-9.165117E-04	-1.563870E-02	0.0
13	G	0.0	-1.115810E-19	0.0	-1.869885E-04	2.978237E-02	0.0
14	G	-1.794663E-20	-1.250619E-19	-8.308844E-02	-2.497156E-03	2.273052E-02	0.0
15	G	-8.558504E-20	-1.460906E-19	-1.305235E-01	-5.125305E-03	7.580590E-03	0.0
16	G	-1.763567E-19	-1.563161E-19	-1.287307E-01	-6.098102E-03	-8.856641E-03	0.0
17	G	-2.526314E-19	-1.483047E-19	-7.953523E-02	-4.516714E-03	-2.280602E-02	0.0
18	G	-2.825843E-19	-1.291995E-19	0.0	-6.436033E-04	-2.735314E-02	0.0
19	G	0.0	-7.106225E-20	0.0	6.436033E-04	2.735314E-02	0.0
20	G	-1.210820E-20	-6.589079E-20	-7.953523E-02	4.516714E-03	2.280602E-02	0.0
21	G	-7.136112E-20	-6.327438E-20	-1.287307E-01	6.098102E-03	8.856641E-03	0.0
22	G	-1.546190E-19	-7.015307E-20	-1.305235E-01	5.125305E-03	-7.580590E-03	0.0
23	G	-2.290863E-19	-8.759032E-20	-8.308844E-02	2.497156E-03	-2.273052E-02	0.0
24	G	-2.619817E-19	-1.198988E-19	0.0	1.869885E-04	-2.978237E-02	0.0
25	G	0.0	-3.792629E-20	0.0	9.165117E-04	1.563870E-02	0.0
26	G	-1.775468E-20	-2.082724E-20	-4.827733E-02	1.106920E-02	1.479205E-02	0.0
27	G	-5.709451E-20	-6.595195E-21	-8.078058E-02	1.696210E-02	6.537446E-03	0.0
28	G	-1.067224E-19	-8.386640E-21	-8.471517E-02	1.663885E-02	-3.682787E-03	0.0
29	G	-1.524044E-19	-2.939486E-20	-5.659059E-02	9.983173E-03	-1.411448E-02	0.0
30	G	-1.795011E-19	-8.353070E-20	0.0	-6.716475E-05	-2.187735E-02	0.0
31	G	0.0	0.0	0.0	-1.190341E-04	-4.164566E-04	0.0
32	G	-3.228108E-20	0.0	0.0	1.161163E-02	8.255243E-04	0.0
33	G	-5.761368E-20	0.0	0.0	2.066866E-02	5.393717E-04	0.0
34	G	-7.971998E-20	0.0	0.0	2.286059E-02	-1.153546E-04	0.0
35	G	-9.792119E-20	0.0	0.0	1.668269E-02	2.098859E-04	0.0
36	G	-1.171910E-19	0.0	0.0	1.210504E-03	-1.323176E-03	0.0

* * * END OF JOB * * *

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 1
TIME 10
CEND

                    C A S E   C O N T R O L   D E C K   E C H O

     1      TITLE = PROBLEM 13  CASE 2   PRESSURE LOAD
     2      LOAD = 1
     3      SPC  = 1
     4      OUTPUT
     5         OLOAD=ALL
     6         STRESS=ALL
     7         DISPLACEMENTS=ALL
     8         STRAIN=ALL
     9      BEGIN BULK
                         S O R T E D   B U L K   D A T A   E C H O
 CARD
 COUNT        .  1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  10  .
    1-        CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
    2-        +XYP    1.0     0.0     1.0
    3-        CQUAD4  1       1       1       2       8       7       1
    4-        CQUAD4  2       1       2       3       9       8       1
    5-        CQUAD4  3       1       3       4       10      9       1
    6-        CQUAD4  4       1       4       5       11      10      1
    7-        CQUAD4  5       1       5       6       12      11      1
    8-        CQUAD4  5       1       7       8       14      13      1
    9-        CQUAD4  7       1       8       9       15      14      1
   10-        CQUAD4  8       1       9       10      16      15      1
   11-        CQUAD4  9       1       10      11      17      16      1
   12-        CQUAD4  10      1       11      12      18      17      1
   13-        CQUAD4  11      1       13      14      20      19      1
   14-        CQUAD4  12      1       14      15      21      20      1
   15-        CQUAD4  13      1       15      16      22      21      1
   16-        CQUAD4  14      1       16      17      23      22      1
   17-        CQUAD4  15      1       17      18      24      23      1
   18-        CQUAD4  16      1       19      20      26      25      1
   19-        CQUAD4  17      1       20      21      27      26      1
   20-        CQUAD4  18      1       21      22      28      27      1
   21-        CQUAD4  19      1       22      23      29      28      1
   22-        CQUAD4  20      1       23      24      30      29      1
   23-        CQUAD4  21      1       25      26      32      31      1
   24-        CQUAD4  22      1       26      27      33      32      1
   25-        CQUAD4  23      1       27      28      34      33      1
   26-        CQUAD4  24      1       28      29      35      34      1
   27-        CQUAD4  25      1       29      30      36      35      1
   28-        GRID    1               0.0     0.0     0.0
   29-        GRID    2               3.0     0.0     0.0
   30-        GRID    3               6.0     0.0     0.0
   31-        GRID    4               9.0     0.0     0.0
   32-        GRID    5               12.0    0.0     0.0
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33-     GRID    6               15.0    0.0     0.0
34-     GRID    7               0.0     4.0     0.0
35-     GRID    8               3.0     4.0     0.0
36-     GRID    9               6.0     4.0     0.0
37-     GRID    10              9.0     4.0     0.0
38-     GRID    11              12.0    4.0     0.0
39-     GRID    12              15.0    4.0     0.0
40-     GRID    13              0.0     8.0     0.0
41-     GRID    14              3.0     8.0     0.0
42-     GRID    15              6.0     8.0     0.0
43-     GRID    16              9.0     8.0     0.0
44-     GRID    17              12.0    8.0     0.0
45-     GRID    18              15.0    8.0     0.0
46-     GRID    19              0.0     12.0    0.0
47-     GRID    20              3.0     12.0    0.0
48-     GRID    21              6.0     12.0    0.0
49-     GRID    22              9.0     12.0    0.0
50-     GRID    23              12.0    12.0    0.0
51-     GRID    24              15.0    12.0    0.0
52-     GRID    25              0.0     16.0    0.0
53-     GRID    26              3.0     16.0    0.0
54-     GRID    27              6.0     16.0    0.0
55-     GRID    28              9.0     16.0    0.0
56-     GRID    29              12.0    16.0    0.0
57-     GRID    30              15.0    16.0    0.0
58-     GRID    31              0.0     20.0    0.0
59-     GRID    32              3.0     20.0    0.0
60-     GRID    33              6.0     20.0    0.0
61-     GRID    34              9.0     20.0    0.0
62-     GRID    35              12.0    20.0    0.0
63-     GRID    36              15.0    20.0    0.0
64-     MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
65-     PCOMP   1                                                               +KKP
66-     +KKP    22      .0236   45.0    YES     22      .0236   -45.0   YES     +KKQ
67-     +KKQ    22      .0236   90.0    YES     22      .0236   0.0     YES     +KKS
68-     +KKS    22      .0236   0.0     YES     22      .0236   90.0    YES     +KKR
69-     +KKR    22      .0236   -45.0   YES     22      .0236   45.0    YES
70-     PLOAD2  1       -2.0    1       THRU    25
71-     SPC1    1       6       1       THRU    36
72-     SPC1    1       36      1       THRU    6
73-     SPC1    1       36      6       12      18      24      30      36
74-     SPC1    1       136     1       7       13      19      25      31
75-     SPC1    1       236     31      THRU    36
        ENDDATA
  TOTAL COUNT=    75
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	-1.659534E-03	1.630020E-03	0.0
2	G	0.0	0.0	0.0	-1.568235E-02	-2.294436E-04	0.0
3	G	0.0	0.0	0.0	-2.187067E-02	3.227942E-05	0.0
4	G	0.0	0.0	0.0	-1.995040E-02	-5.664070E-04	0.0
5	G	0.0	0.0	0.0	-1.137580E-02	-9.744150E-04	0.0
6	G	0.0	0.0	0.0	3.201080E-04	5.167978E-04	0.0
7	G	0.0	0.0	0.0	1.627950E-04	2.099241E-02	0.0
8	G	0.0	0.0	-5.535023E-02	-9.825311E-03	1.395945E-02	0.0
9	G	0.0	0.0	-8.360141E-02	-1.605320E-02	3.755062E-03	0.0
10	G	0.0	0.0	-8.008110E-02	-1.632954E-02	-6.392517E-03	0.0
11	G	0.0	0.0	-4.817439E-02	-1.067774E-02	-1.449008E-02	0.0
12	G	0.0	0.0	0.0	-1.202066E-03	-1.558065E-02	0.0
13	G	0.0	0.0	0.0	-4.916388E-05	2.914780E-02	0.0
14	G	0.0	0.0	-8.209246E-02	-2.443614E-03	2.221869E-02	0.0
15	G	0.0	0.0	-1.288863E-01	-5.031536E-03	7.453628E-03	0.0
16	G	0.0	0.0	-1.272077E-01	-5.982229E-03	-8.663215E-03	0.0
17	G	0.0	0.0	-7.872557E-02	-4.491668E-03	-2.233347E-02	0.0
18	G	0.0	0.0	0.0	-6.876041E-04	-2.682007E-02	0.0
19	G	0.0	0.0	0.0	6.876041E-04	2.682007E-02	0.0
20	G	0.0	0.0	-7.872557E-02	4.491668E-03	2.233347E-02	0.0
21	G	0.0	0.0	-1.272077E-01	5.982229E-03	8.663215E-03	0.0
22	G	0.0	0.0	-1.288863E-01	5.031536E-03	-7.453628E-03	0.0
23	G	0.0	0.0	-8.209246E-02	2.443614E-03	-2.221869E-02	0.0
24	G	0.0	0.0	0.0	4.916388E-05	-2.914780E-02	0.0
25	G	0.0	0.0	0.0	1.202066E-03	1.558065E-02	0.0
26	G	0.0	0.0	-4.817439E-02	1.067774E-02	1.449008E-02	0.0
27	G	0.0	0.0	-8.008110E-02	1.632954E-02	6.392517E-03	0.0
28	G	0.0	0.0	-8.360141E-02	1.605320E-02	-3.755062E-03	0.0
29	G	0.0	0.0	-5.535023E-02	9.825311E-03	-1.395945E-02	0.0
30	G	0.0	0.0	0.0	-1.627950E-04	-2.099241E-02	0.0
31	G	0.0	0.0	0.0	-3.201080E-04	-5.167978E-04	0.0
32	G	0.0	0.0	0.0	1.137580E-02	9.744150E-04	0.0
33	G	0.0	0.0	0.0	1.995040E-02	5.664070E-04	0.0
34	G	0.0	0.0	0.0	2.187067E-02	-3.227942E-05	0.0
35	G	0.0	0.0	0.0	1.568235E-02	2.294436E-04	0.0
36	G	0.0	0.0	0.0	1.659534E-03	-1.630020E-03	0.0

* * * END OF JOB * * *

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 3,0
TIME 10
CEND

                    C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      METHOD = 1
  2      SPC   = 1
  3      OUTPUT
  4         DISPLACEMENTS(PRINT,PUNCH)=ALL
  5      BEGIN BULK
CARD
COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
   1-        CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +ABC
   2-        +ABC    1.0     0.0     1.0
   3-        CQUAD4  1       1       1       2       8       7       1
   4-        CQUAD4  2       1       2       3       9       8       1
   5-        CQUAD4  3       1       3       4       10      9       1
   6-        CQUAD4  4       1       4       5       11      10      1
   7-        CQUAD4  5       1       5       6       12      11      1
   8-        CQUAD4  6       1       7       8       14      13      1
   9-        CQUAD4  7       1       8       9       15      14      1
  10-        CQUAD4  8       1       9       10      16      15      1
  11-        CQUAD4  9       1       10      11      17      16      1
  12-        CQUAD4  10      1       11      12      18      17      1
  13-        CQUAD4  11      1       13      14      20      19      1
  14-        CQUAD4  12      1       14      15      21      20      1
  15-        CQUAD4  13      1       15      16      22      21      1
  16-        CQUAD4  14      1       16      17      23      22      1
  17-        CQUAD4  15      1       17      18      24      23      1
  18-        CQUAD4  16      1       19      20      26      25      1
  19-        CQUAD4  17      1       20      21      27      26      1
  20-        CQUAD4  18      1       21      22      28      27      1
  21-        CQUAD4  19      1       22      23      29      28      1
  22-        CQUAD4  20      1       23      24      30      29      1
  23-        CQUAD4  21      1       25      26      32      31      1
  24-        CQUAD4  22      1       26      27      33      32      1
  25-        CQUAD4  23      1       27      28      34      33      1
  26-        CQUAD4  24      1       28      29      35      34      1
  27-        CQUAD4  25      1       29      30      36      35      1
  28-        EIGP    1       INV     0.0     100.    20      6                       +WXY
  29-        +WXY    MAX
```

```
GRID    1               0.0     0.0     0.0
GRID    2               3.0     0.0     0.0
GRID    3               6.0     0.0     0.0
GRID    4               9.0     0.0     0.0
GRID    5               12.0    0.0     0.0
GRID    6               15.0    0.0     0.0
GRID    7               0.0     4.0     0.0
GRID    8               3.0     4.0     0.0
GRID    9               6.0     4.0     0.0
GRID    10              9.0     4.0     0.0
GRID    11              12.0    4.0     0.0
GRID    12              15.0    4.0     0.0
GRID    13              0.0     8.0     0.0
GRID    14              3.0     8.0     0.0
GRID    15              6.0     8.0     0.0
GRID    16              9.0     8.0     0.0
GRID    17              12.0    8.0     0.0
GRID    18              15.0    8.0     0.0
GRID    19              0.0     12.0    0.0
GRID    20              3.0     12.0    0.0
GRID    21              6.0     12.0    0.0
GRID    22              9.0     12.0    0.0
GRID    23              12.0    12.0    0.0
GRID    24              15.0    12.0    0.0
GRID    25              0.0     16.0    0.0
GRID    26              3.0     16.0    0.0
GRID    27              6.0     16.0    0.0
GRID    28              9.0     16.0    0.0
GRID    29              12.0    16.0    0.0
GRID    30              15.0    16.0    0.0
GRID    31              0.0     20.0    0.0
GRID    32              3.0     20.0    0.0
GRID    33              6.0     20.0    0.0
GRID    34              9.0     20.0    0.0
GRID    35              12.0    20.0    0.0
GRID    36              15.0    20.0    0.0
MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
PARAM   GRDPNT  0
PCOMP1  1                                       22      .0236   SYM     ABC
+BC     45.0    -45.0   90.     0.0
SPC1    1       6       1       THRU    36
SPC1    1       36      1       THRU    6
SPC1    1       36      6       12      18      24      30      36
SPC1    1       136     1       7       13      19      25      31
SPC1    1       236     31      THRU    36
ENDDATA
```

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIAN FREQUENCY	CYCLIC FREQUENCY	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	2.206153E+04	1.485312E+02	2.363948E+01	8.482909E-02	1.871459E+03
2	2	9.134000E+04	3.022251E+02	4.810061E+01	8.233906E-02	7.520849E+03
3	3	1.469552E+05	3.833473E+02	6.101162E+01	7.691807E-02	1.130351E+04
4	4	2.678465E+05	5.175388E+02	8.236886E+01	6.337978E-02	1.697605E+04
5	5	3.130839E+05	5.595389E+02	8.905338E+01	6.320361E-02	1.978803E+04
6	6	5.373900E+05	7.330688E+02	1.166715E+02	5.950838E-02	3.197921E+04

* * * END OF JOB * * *

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N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 3
TIME 10
CEND
```

```
                    C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1       METHOD = 1
  2       SPC  = 1
  3       OUTPUT
  4          DISPLACEMENTS(PRINT,PUNCH)=ALL
  5       BEGIN BULK
```

```
                         S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT        .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
    1-       CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +ABC
    2-       +ABC    1.0     0.0     1.0
    3-       CQUAD4  1       1       1       2       3       7       1
    4-       CQUAD4  2       1       2       3       9       8       1
    5-       CQUAD4  3       1       3       4       10      9       1
    6-       CQUAD4  4       1       4       5       11      10      1
    7-       CQUAD4  5       1       5       5       12      11      1
    8-       CQUAD4  6       1       7       8       14      13      1
    9-       CQUAD4  7       1       8       9       15      14      1
   10-       CQUAD4  8       1       9       10      16      15      1
   11-       CQUAD4  9       1       10      11      17      16      1
   12-       CQUAD4  10      1       11      12      18      17      1
   13-       CQUAD4  11      1       13      14      20      19      1
   14-       CQUAD4  12      1       14      15      21      20      1
   15-       CQUAD4  13      1       15      16      22      21      1
   16-       CQUAD4  14      1       16      17      23      22      1
   17-       CQUAD4  15      1       17      18      24      23      1
   18-       CQUAD4  16      1       19      20      26      25      1
   19-       CQUAD4  17      1       20      21      27      26      1
   20-       CQUAD4  18      1       21      22      28      27      1
   21-       CQUAD4  19      1       22      23      29      28      1
   22-       CQUAD4  20      1       23      24      30      29      1
   23-       CQUAD4  21      1       25      26      32      31      1
   24-       CQUAD4  22      1       26      27      33      32      1
   25-       CQUAD4  23      1       27      28      34      33      1
   26-       CQUAD4  24      1       28      29      35      34      1
   27-       CQUAD4  25      1       29      30      36      35      1
   28-       EIGR    1       INV     0.0     100.    20      6                       +WXY
   29-       +WXY    MAX
   30-       GRID    1               0.0     0.0     0.0
   31-       GRID    2               3.0     0.0     0.0
   32-       GRID    3               6.0     0.0     0.0
   33-       GRID    4               9.0     0.0     0.0
```

```
GRID    5               12.0    0.0     0.0
GRID    6               15.0    0.0     0.0
GRID    7               0.0     4.0     0.0
GRID    8               3.0     4.0     0.0
GRID    9               6.0     4.0     0.0
GRID    10              9.0     4.0     0.0
GRID    11              12.0    4.0     0.0
GRID    12              15.0    4.0     0.0
GRID    13              0.0     8.0     0.0
GRID    14              3.0     8.0     0.0
GRID    15              6.0     8.0     0.0
GRID    16              9.0     8.0     0.0
GRID    17              12.0    8.0     0.0
GRID    18              15.0    8.0     0.0
GRID    19              0.0     12.0    0.0
GRID    20              3.0     12.0    0.0
GRID    21              6.0     12.0    0.0
GRID    22              9.0     12.0    0.0
GRID    23              12.0    12.0    0.0
GRID    24              15.0    12.0    0.0
GRID    25              0.0     16.0    0.0
GRID    26              3.0     16.0    0.0
GRID    27              6.0     16.0    0.0
GRID    28              9.0     16.0    0.0
GRID    29              12.0    16.0    0.0
GRID    30              15.0    16.0    0.0
GRID    31              0.0     20.0    0.0
GRID    32              3.0     20.0    0.0
GRID    33              5.0     20.0    0.0
GRID    34              9.0     20.0    0.0
GRID    35              12.0    20.0    0.0
GRID    36              15.0    20.0    0.0
MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
PARAM   GRDPNT  0
PCOMP   1                                                       +KKP
+KKP    22      .0236   45.0    YES     22      .0236   -45.0   YES     +KKQ
+KKQ    22      .0236   90.0    YES     22      .0236   0.0     YES     +KKS
+KKS    22      .0236   0.0     YES     22      .0236   90.0    YES     +KKR
+KKR    22      .0236   -45.0   YES     22      .0236   45.0    YES
SPC1    1       6       1       THRU    36
SPC1    1       36      1       THRU    6
SPC1    1       36      6       12      18      24      30      36
SPC1    1       136     1       7       13      19      25      31
SPC1    1       236     31      THRU    36
ENDDATA
```

R E A L   E I G E N V A L U E S

MODE NO.	EXTRACTION ORDER	EIGENVALUE	RADIANS	CYCLES	GENERALIZED MASS	GENERALIZED STIFFNESS
1	1	2.232679E+04	1.494215E+02	2.378117E+01	8.489105E-02	1.895345E+03
2	2	9.354261E+04	3.058474E+02	4.867712E+01	8.149919E-02	7.623547E+03
3	3	1.493206E+05	3.864202E+02	6.150068E+01	7.644512E-02	1.141483E+04
4	4	2.815449E+05	5.306080E+02	8.444889E+01	6.521134E-02	1.835992E+04
5	5	3.217625E+05	5.672411E+02	9.027923E+01	6.557091E-02	2.109826E+04
6	6	5.805212E+05	7.619194E+02	1.212632E+02	7.699291E-02	4.469601E+04

* * * END OF JOB * * *

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 1,0
TIME 10
CEND

                C A S E   C O N T R O L   D E C K   E C H O

     1      TITLE =   PROBLEM 14  SANDWICH PLATE  COMPOSITE FACE SHEETS
     2      LOAD = 1
     3      SPC  = 1
     4      OUTPUT
     5         OLOAD=ALL
     6         STRESS=ALL
     7         DISPLACEMENTS=ALL
     8         STRAIN=ALL
     9      BEGIN BULK
                      S O R T E D   B U L K   D A T A   E C H O
 CARD
 COUNT        ---1--- +++2+++ ---3--- +++4+++ ---5--- +++6+++ ---7--- +++8+++ ---9--- +++10+++
    1-        CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
    2-        +XYP    1.0     0.0     1.0
    3-        CQUAD4  1       72      1       2       8       7       1
    4-        CQUAD4  2       72      2       3       9       8       1
    5-        CQUAD4  3       72      3       4       10      9       1
    6-        CQUAD4  4       72      4       5       11      10      1
    7-        CQUAD4  5       72      5       6       12      11      1
    8-        CQUAD4  6       72      7       8       14      13      1
    9-        CQUAD4  7       72      8       9       15      14      1
   10-        CQUAD4  8       72      9       10      16      15      1
   11-        CQUAD4  9       72      10      11      17      16      1
   12-        CQUAD4  10      72      11      12      18      17      1
   13-        CQUAD4  11      72      13      14      20      19      1
   14-        CQUAD4  12      72      14      15      21      20      1
   15-        CQUAD4  13      72      15      16      22      21      1
   16-        CQUAD4  14      72      16      17      23      22      1
   17-        CQUAD4  15      72      17      18      24      23      1
   18-        CQUAD4  16      72      19      20      26      25      1
   19-        CQUAD4  17      72      20      21      27      26      1
   20-        CQUAD4  18      72      21      22      28      27      1
   21-        CQUAD4  19      72      22      23      29      28      1
   22-        CQUAD4  20      72      23      24      30      29      1
   23-        CQUAD4  21      72      25      26      32      31      1
   24-        CQUAD4  22      72      26      27      33      32      1
   25-        CQUAD4  23      72      27      28      34      33      1
   26-        CQUAD4  24      72      28      29      35      34      1
   27-        CQUAD4  25      72      29      30      36      35      1
   28-        GRID    1               0.0     0.0     0.0
   29-        GRID    2               3.0     0.0     0.0
   30-        GRID    3               6.0     0.0     0.0
```

```
31-      GRID    4                9.0     0.0     0.0
32-      GRID    5                12.0    0.0     0.0
33-      GRID    6                15.0    0.0     0.0
34-      GRID    7                0.0     4.0     0.0
35-      GRID    8                3.0     4.0     0.0
36-      GRID    9                6.0     4.0     0.0
37-      GRID    10               9.0     4.0     0.0
38-      GRID    11               12.0    4.0     0.0
39-      GRID    12               15.0    4.0     0.0
40-      GRID    13               0.0     8.0     0.0
41-      GRID    14               3.0     8.0     0.0
42-      GRID    15               6.0     8.0     0.0
43-      GRID    16               9.0     8.0     0.0
44-      GRID    17               12.0    8.0     0.0
45-      GRID    18               15.0    8.0     0.0
46-      GRID    19               0.0     12.0    0.0
47-      GRID    20               3.0     12.0    0.0
48-      GRID    21               6.0     12.0    0.0
49-      GRID    22               9.0     12.0    0.0
50-      GRID    23               12.0    12.0    0.0
51-      GRID    24               15.0    12.0    0.0
52-      GRID    25               0.0     16.0    0.0
53-      GRID    26               3.0     16.0    0.0
54-      GRID    27               6.0     16.0    0.0
55-      GRID    28               9.0     16.0    0.0
56-      GRID    29               12.0    16.0    0.0
57-      GRID    30               15.0    16.0    0.0
58-      GRID    31               0.0     20.0    0.0
59-      GRID    32               3.0     20.0    0.0
60-      GRID    33               6.0     20.0    0.0
61-      GRID    34               9.0     20.0    0.0
62-      GRID    35               12.0    20.0    0.0
63-      GRID    36               15.0    20.0    0.0
64-      MAT1    10               3.0E+04 .25
65-      MAT8    22      18.5E+061.6E+06 .25     .55E+06 4.0E+05 4.0E+05 .005
66-      PCOMP   72                                                              +ABC
67-      +ABC    22      .0236   45.     YES     22      .0236   -45.    YES     +DEF
68-      +DEF    22      .0236   90.     YES     22      .0236   0.0     YES     +EFG
69-      +EFG    10      1.0     0.0             22      .0236   0.0     YES     +FGH
70-      +FGH    22      .0236   90.0    YES     22      .0236   -45.0   YES     +GHI
71-      +GHI    22      .0236   45.0    YES
72-      PLOAD2  1       -2.0    1       THRU    25
73-      SPC1    1       6       1       THRU    36
74-      SPC1    1       36      1       THRU    6
75-      SPC1    1       36      6       12      18      24      30      36
76-      SPC1    1       136     1       7       13      19      25      31
77-      SPC1    1       236     31      THRU    36
         ENDDATA
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	-1.262361E-21	0.0	-1.143164E-04	7.499255E-05	0.0
2	G	-4.790143E-22	-3.355112E-21	0.0	-1.790529E-04	7.432398E-05	0.0
3	G	-2.955672E-22	-4.562165E-21	0.0	-2.559781E-04	4.713882E-05	0.0
4	G	-1.264729E-22	-3.982578E-21	0.0	-2.455365E-04	-1.063998E-05	0.0
5	G	-3.145644E-22	-1.929802E-21	0.0	-1.535654E-04	-5.459381E-05	0.0
6	G	-6.515719E-22	-4.187489E-22	0.0	-9.322596E-05	-6.597897E-05	0.0
7	G	0.0	-1.765623E-21	0.0	-1.063590E-04	2.292916E-04	0.0
8	G	1.332215E-21	-3.720921E-21	-9.309109E-04	-1.386407E-04	1.791623E-04	0.0
9	G	1.130583E-21	-4.489881E-21	-1.361827E-03	-1.983930E-04	6.680239E-05	0.0
10	G	6.925907E-23	-3.550335E-21	-1.314377E-03	-1.916281E-04	-5.423765E-05	0.0
11	G	-1.060839E-21	-1.285317E-21	-8.131079E-04	-1.148891E-04	-1.635653E-04	0.0
12	G	-1.756958E-21	8.511079E-22	0.0	-7.354622E-05	-2.062164E-04	0.0
13	G	0.0	-3.076516E-21	0.0	-6.418965E-05	3.436314E-04	0.0
14	G	9.844685E-22	-4.408565E-21	-1.309181E-03	-5.804963E-05	2.753212E-04	0.0
15	G	2.347015E-22	-4.176753E-21	-2.026409E-03	-6.767749E-05	9.872849E-05	0.0
16	G	-1.484854E-21	-2.611802E-21	-2.008277E-03	-5.978833E-05	-1.001152E-04	0.0
17	G	-3.134186E-21	-2.276627E-23	-1.272991E-03	-2.516000E-05	-2.728444E-04	0.0
18	G	-4.084607E-21	3.144208E-21	0.0	-1.208915E-05	-3.363470E-04	0.0
19	G	0.0	-3.969974E-21	0.0	1.208915E-05	3.363470E-04	0.0
20	G	-3.581725E-22	4.373653E-21	-1.272991E-03	2.516000E-05	2.728444E-04	0.0
21	G	-2.106983E-21	-3.416818E-21	-2.008277E-03	5.978833E-05	1.001152E-04	0.0
22	G	-4.344522E-21	-1.542182E-21	-2.026409E-03	6.767749E-05	-9.872849E-05	0.0
23	G	-6.108684E-21	1.052242E-21	-1.309181E-03	5.804963E-05	-2.753212E-04	0.0
24	G	-6.847433E-2[illegible]	4.573085E-21	0.0	6.418965E-05	-3.436314E-04	0.0
25	G	0.0	-3.377656E-21	0.0	7.354622E-05	2.062164E-04	0.0
26	G	-2.382802E-21	-2.936029E-21	-8.131079E-04	1.148891E-04	1.635653E-04	0.0
27	G	-5.172902E-21	-1.979701E-21	-1.314377E-03	1.916281E-04	5.423765E-05	0.0
28	G	-7.664944E-21	-5.526538E-22	-1.361827E-03	1.983930E-04	-6.680239E-05	0.0
29	G	-9.268735E-21	1.075791E-21	-9.309109E-04	1.386407E-04	-1.791623E-04	0.0
30	G	-9.495322E-21	3.923865E-21	0.0	1.063590E-04	-2.292916E-04	0.0
31	G	0.0	0.0	0.0	9.322596E-05	6.597897E-05	0.0
32	G	-4.600099E-21	0.0	0.0	1.535654E-04	5.459381E-05	0.0
33	G	-8.168351E-21	0.0	0.0	2.455365E-04	1.063998E-05	0.0
34	G	-1.056813E-20	0.0	0.0	2.559781E-04	-4.713882E-05	0.0
35	G	-1.165361E-20	0.0	0.0	1.790529E-04	-7.432398E-05	0.0
36	G	-1.132367E-20	0.0	0.0	1.143164E-04	-7.499255E-05	0.0

* * * END OF JOB * * *

```
N A S T R A N   E X E C U T I V E   C O N T R O L   D E C K   E C H O

ID    COMPOSITE PLATE  15 BY 20  NASTRAN USERS COLLOQUIUM  1990
APP DISPLACEMENT
SOL 1
TIME 10
CEND

                    C A S E   C O N T R O L   D E C K   E C H O
CARD
COUNT
  1      TITLE =   PROBLEM 14  SANDWICH PLATE  COMPOSITE FACE SHEETS
  2      LOAD = 1
  3      SPC  = 1
  4      OUTPUT
  5         OLOAD=ALL
  6         STRESS=ALL
  7         DISPLACEMENTS=ALL
  8         STRAIN=ALL
  9      BEGIN BULK
              INPUT BULK DATA CARD COUNT =      78
                              S O R T E D   B U L K   D A T A   E C H O
CARD
COUNT         .   1  ..   2  ..   3  ..   4  ..   5  ..   6  ..   7  ..   8  ..   9  ..  10  .
   1-         CORD2R  1               0.0     0.0     0.0     0.0     0.0     1.0     +XYP
   2-         +XYP    1.0     0.0     1.0
   3-         CQUAD4  1       72      1       2       8       7       1
   4-         CQUAD4  2       72      2       3       9       8       1
   5-         CQUAD4  3       72      3       4       10      9       1
   6-         CQUAD4  4       72      4       5       11      10      1
   7-         CQUAD4  5       72      5       6       12      11      1
   8-         CQUAD4  6       72      7       8       14      13      1
   9-         CQUAD4  7       72      8       9       15      14      1
  10-         CQUAD4  8       72      9       10      16      15      1
  11-         CQUAD4  9       72      10      11      17      16      1
  12-         CQUAD4  10      72      11      12      18      17      1
  13-         CQUAD4  11      72      13      14      20      19      1
  14-         CQUAD4  12      72      14      15      21      20      1
  15-         CQUAD4  13      72      15      16      22      21      1
  16-         CQUAD4  14      72      16      17      23      22      1
  17-         CQUAD4  15      72      17      18      24      23      1
  18-         CQUAD4  16      72      19      20      26      25      1
  19-         CQUAD4  17      72      20      21      27      26      1
  20-         CQUAD4  18      72      21      22      28      27      1
  21-         CQUAD4  19      72      22      23      29      28      1
  22-         CQUAD4  20      72      23      24      30      2[illegible]  1
  23-         CQUAD4  21      72      25      26      32      31      1
  24-         CQUAD4  22      72      26      27      33      32      1
  25-         CQUAD4  23      72      27      28      34      33      1
  26-         CQUAD4  24      72      28      29      35      34      1
  27-         CQUAD4  25      72      29      30      36      35      1
  28-         GRID    1               0.0     0.0     0.0
```

```
GRID    2               3.0     0.0     0.0
GRID    3               6.0     0.0     0.0
GRID    4               9.0     0.0     0.0
GRID    5               12.0    0.0     0.0
GRID    6               15.0    0.0     0.0
GRID    7               0.0     4.0     0.0
GRID    8               3.0     4.0     0.0
GRID    9               6.0     4.0     0.0
GRID    10              9.0     4.0     0.0
GRID    11              12.0    4.0     0.0
GRID    12              15.0    4.0     0.0
GRID    13              0.0     8.0     0.0
GRID    14              3.0     8.0     0.0
GRID    15              6.0     8.0     0.0
GRID    16              9.0     8.0     0.0
GRID    17              12.0    8.0     0.0
GRID    18              15.0    8.0     0.0
GRID    19              0.0     12.0    0.0
GRID    20              3.0     12.0    0.0
GRID    21              6.0     12.0    0.0
GRID    22              9.0     12.0    0.0
GRID    23              12.0    12.0    0.0
GRID    24              15.0    12.0    0.0
GRID    25              0.0     16.0    0.0
GRID    26              3.0     16.0    0.0
GRID    27              6.0     16.0    0.0
GRID    28              9.0     16.0    0.0
GRID    29              12.0    16.0    0.0
GRID    30              15.0    16.0    0.0
GRID    31              0.0     20.0    0.0
GRID    32              3.0     20.0    0.0
GRID    33              6.0     20.0    0.0
GRID    34              9.0     20.0    0.0
GRID    35              12.0    20.0    0.0
GRID    36              15.0    20.0    0.0
MAT1    10              3.0E+04 .25
MAT8    22      18.5E+061.6E+06 .25     .65E+06 4.0E+05 4.0E+05 .005
PCOMP   72                                                              +ABC
+ABC    22      .0236   45.     YES     22      .0236   -45.    YES     +DEF
+DEF    22      .0236   90.     YES     22      .0236   0.0     YES     +EFG
+EFG    10      1.0     0.0             22      .0236   0.0     YES     +FGH
+FGH    22      .0236   90.0    YES     22      .0236   -45.0   YES     +GHI
+GHI    22      .0236   45.0    YES
PLOAD2  1       -2.0    1       THRU    25
SPC1    1       6       1       THRU    36
SPC1    1       36      1       THRU    6
SPC1    1       36      6       12      18      24      30      36
SPC1    1       136     1       7       13      19      25      31
SPC1    1       236     31      THRU    36
ENDDATA
```

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	-1.571077E-04	1.142508E-04	0.0
2	G	0.0	0.0	0.0	-1.933766E-04	9.752589E-05	0.0
3	G	0.0	0.0	0.0	-2.608906E-04	3.743675E-05	0.0
4	G	0.0	0.0	0.0	-2.607035E-04	-4.376641E-05	0.0
5	G	0.0	0.0	0.0	-1.934224E-04	-1.008716E-04	0.0
6	G	0.0	0.0	0.0	-1.578756E-04	-1.151408E-04	0.0
7	G	0.0	0.0	0.0	-1.300261E-04	2.268750E-04	0.0
8	G	0.0	0.0	-1.290094E-03	-1.522363E-04	1.820725E-04	0.0
9	G	0.0	0.0	-1.923577E-03	-2.075847E-04	6.413873E-05	0.0
10	G	0.0	0.0	-1.920106E-03	-2.083385E-04	-6.804503E-05	0.0
11	G	0.0	0.0	-1.283585E-03	-1.548241E-04	-1.836399E-04	0.0
12	G	0.0	0.0	0.0	-1.342848E-04	-2.265799E-04	0.0
13	G	0.0	0.0	0.0	-4.759642E-05	3.370894E-04	0.0
14	G	0.0	0.0	-1.845502E-03	-5.010014E-05	2.752919E-04	0.0
15	G	0.0	0.0	-2.815118E-03	-6.906350E-05	1.000706E-04	0.0
16	G	0.0	0.0	-2.813420E-03	-7.083838E-05	-1.013518E-04	0.0
17	G	0.0	0.0	-1.842411E-03	-5.519034E-05	-2.755732E-04	0.0
18	G	0.0	0.0	0.0	-5.532292E-05	-3.366605E-04	0.0
19	G	0.0	0.0	0.0	5.532292E-05	3.366605E-04	0.0
20	G	0.0	0.0	-1.842411E-03	5.519034E-05	2.755732E-04	0.0
21	G	0.0	0.0	-2.813420E-03	7.083838E-05	1.013518E-04	0.0
22	G	0.0	0.0	-2.815118E-03	6.906350E-05	-1.000706E-04	0.0
23	G	0.0	0.0	-1.845502E-03	5.010014E-05	-2.752919E-04	0.0
24	G	0.0	0.0	0.0	4.759642E-05	-3.370894E-04	0.0
25	G	0.0	0.0	0.0	1.342848E-04	2.265799E-04	0.0
26	G	0.0	0.0	-1.283585E-03	1.548241E-04	1.836399E-04	0.0
27	G	0.0	0.0	-1.920106E-03	2.083385E-04	6.804503E-05	0.0
28	G	0.0	0.0	-1.923577E-03	2.075847E-04	-6.413873E-05	0.0
29	G	0.0	0.0	-1.290094E-03	1.522363E-04	-1.820725E-04	0.0
30	G	0.0	0.0	0.0	1.300261E-04	-2.268750E-04	0.0
31	G	0.0	0.0	0.0	1.578756E-04	1.151408E-04	0.0
32	G	0.0	0.0	0.0	1.934224E-04	1.008716E-04	0.0
33	G	0.0	0.0	0.0	2.607035E-04	4.376641E-05	0.0
34	G	0.0	0.0	0.0	2.608906E-04	-3.743675E-05	0.0
35	G	0.0	0.0	0.0	1.933766E-04	-9.752589E-05	0.0
36	G	0.0	0.0	0.0	1.571077E-04	-1.142508E-04	0.0

* * * END OF JOB * * *

PROBLEM #9

REGULAR SYMMETRIC CROSS-PLY LAMINATE

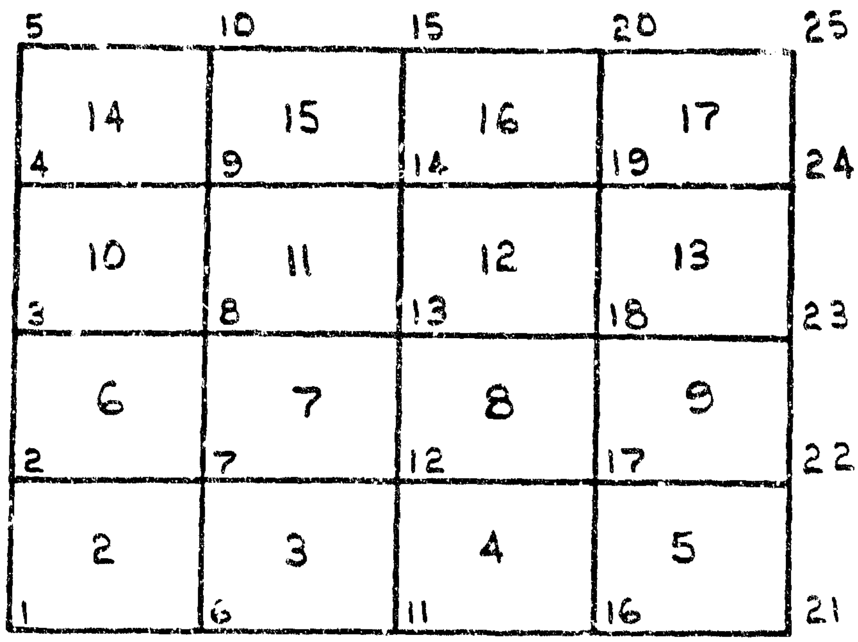


FIGURE 9

A quarter model of a composite square plate modeled as symmetric cross-ply laminate is shown in Fig. 9. The length of each side is 1.0, and the thickness of each ply is .000666. The material properties are given as $E_1=2.0\times10^7$, $E_2=5.0\times10^5$, $\nu_{12}=0.25$ and $G_{12}=2.5\times10^5$ and are the same for each ply. The full plate is simply supported and is subjected to a uniform pressure load of -1.0×10^{-4}. The finite element model contains 25 nodes and 16 elements. The theoretical solution for the Z deflection at Grid 25 (center of the plate) is -1.836×10^{-3}. Theoretical results are also given for the stresses in layers 1 and 3 in element 17 in Table 4.

σ_1	σ_2	τ_{12}
58.6	1.8	-.06

TABLE 4

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH QUAD4 ELEMENTS

COSMIC INPUT

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
1-	CQUAD4	2	1	1	6	7	2			
2-	CQUAD4	3	1	6	11	12	7			
3-	CQUAD4	4	1	11	16	17	12			
4-	CQUAD4	5	1	16	21	22	17			
5-	CQUAD4	6	1	2	7	8	3			
6-	CQUAD4	7	1	7	12	13	8			
7-	CQUAD4	8	1	12	17	18	13			
8-	CQUAD4	9	1	17	22	23	18			
9-	CQUAD4	10	1	3	8	9	4			
10-	CQUAD4	11	1	8	13	14	9			
11-	CQUAD4	12	1	13	18	19	14			
12-	CQUAD4	13	1	18	23	24	19			
13-	CQUAD4	14	1	4	9	10	5			
14-	CQUAD4	15	1	9	14	15	10			
15-	CQUAD4	16	1	14	19	20	15			
16-	CQUAD4	17	1	19	24	25	20			
17-	GRID	1		0.000	0.000	0.000				
18-	GRID	2		0.000	.250	0.000				
19-	GRID	3		0.000	.500	0.000				
20-	GRID	4		0.000	.750	0.000				
21-	GRID	5		0.000	1.000	0.000				
22-	GRID	6		.250	0.000	0.000				
23-	GRID	7		.250	.250	0.000				
24-	GRID	8		.250	.500	0.000				
25-	GRID	9		.250	.750	0.000				
26-	GRID	10		.250	1.000	0.000				
27-	GRID	11		.500	0.000	0.000				
28-	GRID	12		.500	.250	0.000				
29-	GRID	13		.500	.500	0.000				
30-	GRID	14		.500	.750	0.000				

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH QUAD4 ELEMENTS

COSMIC INPUT (CONTD)

```
GRID    15              .500    1.000   0.000
GRID    16              .750    0.000   0.000
GRID    17              .750    .250    0.000
GRID    18              .750    .500    0.000
GRID    19              .750    .750    0.000
GRID    20              .750    1.000   0.000
GRID    21              1.000   0.000   0.000
GRID    22              1.000   .250    0.000
GRID    23              1.000   .500    0.000
GRID    24              1.000   .750    0.000
GRID    25              1.000   1.000   0.000
MAT8    1       20.0E+06.50     E+6.25  .250 E+6
PARAM   AUTOSPC 1
PCOMP   1       -.001                                                   +PC1
+PC1    1       .000666 0.0     YES     1       .000666 90.0    YES     +PC2
+PC2    1       .000666 0.0     YES
PLOAD4  1       2       -1.0E-04                        THRU    17
SPC1    1       15      22      23      24
SPC1    1       24      10      15      20
SPC1    1       1234    2       3       4       5
SPC1    1       1235    6       11      16      21
SPC1    1       1245    25
SPC1    1       12345   1
ENDDATA
```

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH QUAD4 ELEMENTS

COSMIC OUTPUT

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	0.0	0.0	0.0
2	G	0.0	0.0	0.0	0.0	1.259793E-03	0.0
3	G	0.0	0.0	0.0	0.0	2.153710E-03	0.0
4	G	0.0	0.0	0.0	0.0	2.628845E-03	0.0
5	G	0.0	0.0	0.0	0.0	2.772239E-03	0.0
6	G	0.0	0.0	0.0	-1.423199E-03	0.0	0.0
7	G	0.0	0.0	-3.245146E-04	-1.171945E-03	1.144795E-03	0.0
8	G	0.0	0.0	-5.582579E-04	-7.010531E-04	1.969899E-03	0.0
9	G	0.0	0.0	-6.843077E-04	-3.124475E-04	2.410641E-03	0.0
10	G	0.0	0.0	-7.226401E-04	0.0	2.543014E-03	0.0
11	G	0.0	0.0	0.0	-2.575165E-03	0.0	0.0
12	G	0.0	0.0	-5.899490E-04	-2.141997E-03	8.477152E-04	0.0
13	G	0.0	0.0	-1.019073E-03	-1.294632E-03	1.476568E-03	0.0
14	G	0.0	0.0	-1.251502E-03	-5.713850E-04	1.817122E-03	0.0
15	G	0.0	0.0	-1.322001E-03	0.0	1.918498E-03	0.0
16	G	0.0	0.0	0.0	-3.312100E-03	0.0	0.0
17	G	0.0	0.0	-7.614346E-04	-2.775751E-03	4.475691E-04	0.0
18	G	0.0	0.0	-1.319674E-03	-1.693370E-03	7.857787E-04	0.0
19	G	0.0	0.0	-1.623366E-03	-7.425974E-04	9.717189E-04	0.0
20	G	0.0	0.0	-1.715300E-03	0.0	1.026845E-03	0.0
21	G	0.0	0.0	0.0	-3.565219E-03	0.0	0.0
22	G	0.0	0.0	-8.206014E-04	-2.995503E-03	0.0	0.0
23	G	0.0	0.0	-1.423963E-03	-1.834283E-03	0.0	0.0
24	G	0.0	0.0	-1.752818E-03	-8.027037E-04	0.0	0.0
25	G	0.0	0.0	-1.852310E-03	0.0	0.0	0.0

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH TRIA3 ELEMENTS

COSMIC INPUT

S O R T E D   B U L K   D A T A   E C H O

CARD COUNT	---1---	+++2+++	---3---	+++4+++	---5---	+++6+++	---7---	+++8+++	---9---	+++10+++
1-	CTRIA3	1	1	1	6	2				
2-	CTRIA3	2	1	2	6	7	45.0			
3-	CTRIA3	3	1	6	11	7				
4-	CTRIA3	4	1	7	11	12	45.0			
5-	CTRIA3	5	1	11	16	12				
6-	CTRIA3	6	1	12	16	17	45.0			
7-	CTRIA3	7	1	16	21	17				
8-	CTRIA3	8	1	17	21	22	45.0			
9-	CTRIA3	9	1	2	7	3				
10-	CTRIA3	10	1	3	7	8	45.0			
11-	CTRIA3	11	1	7	12	8				
12-	CTRIA3	12	1	8	12	13	45.0			
13-	CTRIA3	13	1	12	17	13				
14-	CTRIA3	14	1	13	17	18	45.0			
15-	CTRIA3	15	1	17	22	18				
16-	CTRIA3	16	1	18	22	23	45.0			
17-	CTRIA3	17	1	3	8	4				
18-	CTRIA3	18	1	4	8	9	45.0			
19-	CTRIA3	19	1	8	13	9				
20-	CTRIA3	20	1	9	13	14	45.0			
21-	CTRIA3	21	1	13	18	14				
22-	CTRIA3	22	1	14	18	19	45.0			
23-	CTRIA3	23	1	18	23	19				
24-	CTRIA3	24	1	19	23	24	45.0			
25-	CTRIA3	25	1	4	9	5				
26-	CTRIA3	26	1	5	9	10	45.0			
27-	CTRIA3	27	1	9	14	10				
28-	CTRIA3	28	1	10	14	15	45.0			
29-	CTRIA3	29	1	14	19	15				
30-	CTRIA3	30	1	15	19	20	45.0			
31-	CTRIA3	31	1	19	24	20				
32-	CTRIA3	32	1	20	4	25	45.0			
33-	GRID	1		0.000	0.000	0.000				
34-	GRID	2		0.000	.250	0.000				
35-	GRID	3		0.000	.500	0.000				

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH TRIA3 ELEMENTS

COSMIC INPUT (CONTD)

```
GRID    4          0.000   .750    0.000
GRID    5          0.000   1.000   0.000
GRID    6          .250    0.000   0.000
GRID    [illegible] .250   .250    0.000
GRID    8          .250    .500    0.000
GRID    9          .250    .750    0.000
GRID    10         .250    1.000   0.000
GRID    11         .500    0.000   0.000
GRID    12         .500    .250    0.000
GRID    13         .500    .500    0.000
GRID    14         .500    .750    0.000
GRID    15         .500    1.000   0.000
GRID    16         .750    0.000   0.000
GRID    17         .750    .250    0.000
GRID    18         .750    .500    0.000
GRID    19         .750    .750    0.000
GRID    20         .750    1.000   0.000
GRID    21         1.000   0.000   0.000
GRID    22         1.000   .250    0.000
GRID    23         1.000   .500    0.000
GRID    24         1.000   .750    0.000
GRID    25         1.000   1.000   0.000
MAT8    1       20.0E+06.50E+6  .25     .250E+6
PCOMP   1       -.001                                           +PC1
+PC1    1       .000666 0.0     YES     1       .000666 90.0    YES     +PC2
+PC2    1       .000666 0.0     YES
PLOAD   1       -1.0E-0417      21      22
PLOAD   1       -1.0E-0419      24      20
PLOAD   1       -1.0E-043       7       8
PLOAD   1       -1.0E-042       7       3
PLOAD   1       -1.0E-0410      14      15
PLOAD   1       -1.0E-0414      19      15
PLOAD   1       -1.0E-0415      19      20
PLOAD   1       -1.0E-0420      24      25
PLOAD   1       -1.0E-0413      18      14
PLOAD   1       -1.0E-0414      18      19
PLOAD   1       -1.0E-0418      23      19
PLOAD   1       -1.0E-048       13      14
PLOAD   1       -1.0E-0419      23      24
```

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH TRIA3 ELEMENTS

COSMIC INPUT (CONTD)

```
PLOAD   1       -1.0E-044       9       8
PLOAD   1       -1.0E-045       9       10
PLOAD   1       -1.0E-049       14      10
PLOAD   1       -1.0E-0411      16      12
PLOAD   1       -1.0E-0413      17      18
PLOAD   1       -1.0E-046       11      7
PLOAD   1       -1.0E-047       11      12
PLOAD   1       -1.0E-0417      22      18
PLOAD   1       -1.0E-048       13      9
PLOAD   1       -1.0E-0418      22      23
PLOAD   1       -1.0E-047       12      8
PLOAD   1       -1.0E-0416      21      17
PLOAD   1       -1.0E-048       12      13
PLOAD   1       -1.0E-0412      16      17
PLOAD   1       -1.0E-0412      17      13
PLOAD   1       -1.0E-044       3       9
PLOAD   1       -1.0E-042       6       7
PLOAD   1       -1.0E-043       8       4
PLOAD   1       -1.0E-041       6       2
SPC1    1       6       1       THRU    25
SPC1    1       15      22      23      24
SPC1    1       24      10      15      20
SPC1    1       1234    2       3       4       5
SPC1    1       1235    6       11      16      21
SPC1    1       1245    25
SPC1    1       12345   1
ENDDATA
```

PROBLEM 9 REGULAR SYMMETRIC CROSS-PLY LAMINATE MODELED WITH TRIA3 ELEMENTS

COSMIC OUTPUT

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
[illegible]	G	0.0	0.0	0.0	0.0	0.0	0.0
[illegible]	G	0.0	0.0	0.0	0.0	1.174108E-03	0.0
3	G	0.0	0.0	0.0	0.0	2.050508E-03	0.0
4	G	0.0	0.0	0.0	0.0	2.331769E-03	0.0
5	G	0.0	0.0	0.0	0.0	2.[illegible]12162E-03	0.0
6	G	0.0	0.0	0.0	-1.205491E-03	0.0	0.0
7	G	0.0	0.0	-2.845027E-04	-1.039763E-03	[illegible]	0.0
8	G	0.0	0.0	-4.949340E-04	-6.172197E-04	1.385620E-03	0.0
9	G	0.0	0.0	-6.108230E-04	-2.823236E-04	2.317570E-03	0.0
10	G	0.0	0.0	-6.506284E-04	0.0	2.433288E-03	0.0
11	G	0.0	0.0	0.0	-2.270027E-03	0.0	0.0
12	G	0.0	0.0	-5.257187E-04	-1.911599E-03	9.228751E-04	0.0
13	G	0.0	0.0	-9.090877E-04	-1.163205E-03	[illegible]	0.0
14	G	0.0	0.0	-1.119404E-03	-5.145338E-04	1.740501E-03	0.0
15	G	0.0	0.0	-1.187044E-03	0.0	1.809347E-03	0.0
16	G	0.0	0.0	0.0	-3.017362E-03	0.0	0.0
17	G	0.0	0.0	-6.807642E-04	-2.467892E-03	4.626815E-04	0.0
18	G	0.0	0.0	-1.183425E-03	-1.520135E-03	7.572556E-04	0.0
19	G	0.0	0.0	-1.453424E-03	-6.559617E-04	[illegible].274684E-04	0.0
20	G	0.0	0.0	-1.536301E-03	0.0	9.534608E-04	0.0
21	G	0.0	0.0	0.0	-3.372213E-03	0.0	0.0
22	G	0.0	0.0	-7.507061E-04	-2.642528E-03	0.0	0.0
23	G	0.0	0.0	-1.281222E-03	-1.624680E-03	0.0	0.0
24	G	0.0	0.0	-1.570614E-03	-6.878410E-04	0.0	0.0
25	G	0.0	0.0	-1.636966E-03	0.0	0.0	0.0

PROBLEM #12

COMPOSITE SHELL ROOF

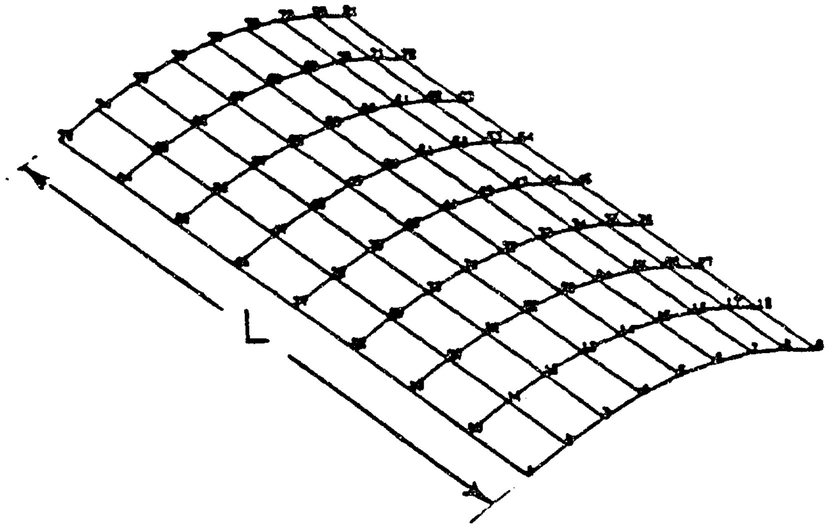


FIGURE 12

A finite element model of a composite shell roof modeled with the symmetric lay-up [45, -45, 15, -15, -15, 15, -45, 45] is shown in Fig. 12. The length and radius of the shell are 25, and the thickness of each layer is .03125. The material properties are given as $E_1=2.0\times10^8$, $E_2=0.5\times10^7$, $\nu_{12}=0.25$, $G_{12}=2.5\times10^6$, and $G_{13}=G_{23}=2.5\times10^6$. The shell is subjected to a uniform pressure of 90.0. Results from MSC/NASTRAN are given in Table 8 for the radial deflection at selected nodes.

GRID	T1
34	-1.0662
35	-1.3441
36	-1.6074
43	-1.3267
44	-1.6739
45	-2.0079

TABLE 8

PROBLEM 12 COMPOSITE SHELL ROOF - CTRIA3 ELEMENTS

COSMIC OUTPUT

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	1.470633E-02	0.0	1.361576E-02	0.0
2	G	0.0	0.0	1.612430E-02	3.240866E-02	7.457397E-03	1.813537E-03
3	G	0.0	0.0	1.942165E-02	1.313583E-01	-7.714272E-03	-5.444880E-03
4	G	0.0	0.0	2.215707E-02	1.976693E-01	-2.931339E-02	-1.551425E-03
5	G	0.0	0.0	2.054040E-02	2.512435E-01	-5.650782E-02	-2.533445E-03
6	G	0.0	0.0	9.672605E-03	2.884153E-01	-8.757029E-02	-3.402307E-03
7	G	0.0	0.0	-1.624594E-02	3.007707E-01	-1.200357E-01	-4.131101E-03
8	G	0.0	0.0	-6.365565E-02	2.776152E-01	-1.504282E-01	-4.490627E-03
9	G	0.0	0.0	-1.393812E-01	0.0	-1.643894E-01	-5.448329E-03
10	G	4.368078E-02	0.0	1.470382E-02	0.0	1.151773E-02	0.0
11	G	2.826459E-02	-3.264060E-03	1.605109E-02	8.395085E-02	8.155208E-03	1.493468E-02
12	G	-1.482768E-02	-3.972457E-03	1.922503E-02	1.250123E-01	-5.081132E-03	2.591116E-02
13	G	-7.955509E-02	4.956841E-05	2.184063E-02	1.604297E-01	-2.528226E-02	3.501230E-02
14	G	-1.617897E-01	1.051910E-02	2.020436E-02	1.832168E-01	-5.096500E-02	4.241037E-02
15	G	-2.555453E-01	2.873136E-02	9.543329E-03	1.904393E-01	-8.039026E-02	4.734479E-02
16	G	-3.567530E-01	5.541337E-02	-1.573482E-02	1.797236E-01	-1.114484E-01	4.872809E-02
17	G	-4.531212E-01	9.051105E-02	-6.169981E-02	1.563861E-01	-1.420324E-01	4.565815E-02
18	G	-5.343321E-01	1.328572E-01	-1.344102E-01	0.0	-1.650618E-01	3.715051E-02
19	G	8.354098E-02	0.0	1.460463E-02	0.0	8.452272E-03	0.0
20	G	5.485842E-02	-6.135858E-03	1.576311E-02	8.662643E-02	5.857764E-03	2.687922E-02
21	G	-2.710054E-02	-7.396237E-03	1.850582E-02	1.249557E-01	-4.624485E-03	4.874576E-02
22	G	-1.524426E-01	4.739278E-04	2.065561E-02	1.543775E-01	-2.283172E-02	6.676597E-02
23	G	-3.120429E-01	2.086395E-02	1.880291E-02	1.705106E-01	-4.615085E-02	8.086339E-02
24	G	-4.952009E-01	5.623504E-02	8.573793E-03	1.721470E-01	-7.276709E-02	9.005839E-02
25	G	-6.886350E-01	1.078973E-01	-1.504325E-02	1.632250E-01	-1.009693E-01	9.333315E-02
26	G	-8.776217E-01	1.757794E-01	-5.733753E-02	1.534643E-01	-1.296031E-01	9.074438E-02
27	G	-1.040164E+00	2.584161E-01	-1.236248E-01	0.0	-1.518993E-01	8.408472E-02
28	G	1.165276E-01	0.0	1.401622E-02	0.0	5.516557E-03	0.0
29	G	7.638276E-02	-8.429410[illegible]03	1.489281E-02	9.887142E-02	5.185639E-03	3.709026E-02
30	G	-3.927651E-02	-9.976236E-03	1.701572E-02	1.280838E-01	-4.640827E-03	6.886443E-02
31	G	-2.181162E-01	1.456814E-03	1.851162E-02	1.488879E-01	-2.028534E-02	9.510006E-02
32	G	-4.463317E-01	3.076088E-02	1.643791E-02	1.580755E-01	-4.040500E-02	1.153411E-01
33	G	-7.077198E-01	8.141620E-02	7.045449E-03	1.553746E-01	-6.342491E-02	1.283439E-01
34	G	-9.838973E-01	1.552550E-01	-1.391042E-02	1.444555E-01	-8.793313E-02	1.336524E-01
35	G	-1.256662E+00	2.523485E-01	-5.089922E-02	1.320263E-01	-1.130087E-01	1.322963E-01
36	G	-1.512646E+00	3.712141E-01	-1.084606E-01	0.0	-1.328700E-01	1.278532E-01
37	G	1.416514E-01	0.0	1.214414E-02	0.0	2.554008E-03	0.0
38	G	9.209161E-02	-1.009582E-02	1.328759E-02	1.049389E-01	3.458303E-03	4.545156E-02
39	G	-5.137531E-02	-1.167172E-02	1.472694E-02	1.227285E-01	-4.346098E-03	8.551660E-02
40	G	-2.747474E-01	2.899282E-03	1.556273E-02	1.362093E-01	-1.685280E-02	1.189154E-01
41	G	-5.604917E-01	3.978039E-02	1.340082E-02	1.394321E-01	-3.318006E-02	1.443206E-01

PROBLEM 12 COMPOSITE SHELL ROOF - CTRIA3 ELEMENTS

COSMIC OUTPUT (CONTD)

42	G	-8.878149E-01	1.033431E-01	5.308660E-03	1.329748E-01	-5.205030E-02	1.606955E-01
43	G	-1.234267E+00	1.959281E-01	-1.222983E-02	1.214679E-01	-7.233550E-02	1.680550E-01
44	G	-1.579237E+00	3.178312E-01	-4.279044E-02	1.141284E-01	-9.345143E-02	1.683716E-01
45	G	-1.909306E+00	4.676761E-01	-9.003448E-02	0.0	-1.103693E-01	1.663368E-01
46	G	1.585377E-01	0.0	1.070312E-02	0.0	-3.328194E-04	0.0
47	G	1.020916E-01	-1.115413E-02	1.092877E-02	9.868991E-02	1.837580E-03	5.151105E-02
48	G	-6.221560E-02	-1.256693E-02	1.171812E-02	1.181452E-01	-3.483323E-03	9.817950E-02
49	G	-3.200940E-01	4.571131E-03	1.201176E-02	1.233944E-01	-1.286091E-02	1.375043E-01
50	G	-6.512789E-01	4.746799E-02	1.006675E-02	1.199054E-01	-2.532743E-02	1.673537E-01
51	G	-1.031257E+00	1.212685E-01	3.596504E-03	1.095177E-01	-3.989144E-02	1.866436E-01
52	G	-1.434353E+00	2.287851E-01	-9.991137E-03	9.726910E-02	-5.572497E-02	1.959045E-01
53	G	-1.838202E+00	3.705621E-01	-3.339332E-02	8.642013E-02	-7.228899E-02	1.979190E-01
54	G	-2.229472E+00	5.453926E-01	-6.932452E-02	0.0	-8.547089E-02	1.981847E-01
55	G	1.668758E-01	0.0	7.928718E-03	0.0	-1.660479E-03	0.0
56	G	1.080008E-01	-1.169142E-02	7.812442E-03	1.191570E-01	1.410222E-03	5.540280E-02
57	G	-7.047822E-02	-1.286581E-02	8.058028E-03	1.048704E-01	-2.586256E-03	1.070393E-01
58	G	-3.529197E-01	6.135389E-03	8.046384E-03	1.046178E-01	-8.673640E-03	1.509624E-01
59	G	-7.173160E-01	5.337095E-02	6.576133E-03	9.723432E-02	-1.716859E-02	1.842807E-01
60	G	-1.136189E+00	1.346256E-01	2.061663E-03	8.429071E-02	-2.724381E-02	2.058199E-01
61	G	-1.561390E+00	2.530920E-01	-7.243007E-03	7.151520E-02	-3.817935E-02	2.166686E-01
62	G	-2.029629E+00	4.095345E-01	-2.309458E-02	7.429327E-02	-5.004312E-02	2.203675E-01
63	G	-2.467970E+00	6.029455E-01	-4.722725E-02	0.0	-6.007985E-02	2.227727E-01
64	G	1.701813E-01	0.0	4.341663E-03	0.0	-6.951285E-03	0.0
65	G	1.092746E-01	-1.175825E-02	4.012782E-03	5.440501E-02	-1.511942E-03	5.643111E-02
66	G	-7.531671E-02	-1.281390E-02	4.029745E-03	1.019095E-01	-9.911236E-04	1.113292E-01
67	G	-3.725972E-01	7.206568E-03	3.976561E-03	9.881937E-02	-4.479322E-03	1.592970E-01
68	G	-7.591181E-01	5.706112E-02	3.171894E-03	8.436854E-02	-1.003476E-02	1.954991E-01
69	G	-1.204372E+00	1.429999E-01	7.929738E-04	6.339596E-02	-1.680591E-02	2.186134E-01
70	G	-1.677765E+00	2.684475E-01	-4.026215E-03	4.313026E-02	-2.403195E-02	2.302631E-01
71	G	-2.155000E+00	4.342831E-01	-1.209223E-02	1.261471E-02	-3.079130E-02	2.346718E-01
72	G	-2.624267E+00	6.396778E-01	-2.407040E-02	0.0	-3.432402E-02	2.395364E-01
73	G	1.669936E-01	0.0	0.0	-6.855840E-02	0.0	0.0
74	G	1.072161E-01	-1.189289E-02	0.0	1.943815E-01	0.0	5.693102E-02
75	G	-7.771776E-02	-1.293488E-02	0.0	1.544966E-01	0.0	1.154741E-01
76	G	-3.814610E-01	7.504007E-03	0.0	1.241305E-01	0.0	1.650839E-01
77	G	-7.779930E-01	5.849575E-02	0.0	8.962283E-02	0.0	2.022918E-01
78	G	-1.235319E+00	1.464317E-01	0.0	5.829034E-02	0.0	2.257639E-01
79	G	-1.721251E+00	2.747352E-01	0.0	4.354954E-02	0.0	2.374775E-01
80	G	-2.211140E+00	4.441634E-01	0.0	9.365131E-02	0.0	2.441724E-01
81	G	-2.697074E+00	6.738841E-01	0.0	-3.394089E-01	0.0	2.429941E-01
5001	G	0.0	0.0	0.0	0.0	0.0	0.0

PROBLEM 12 COMPOSITE SHELL ROOF - CTRIA3 ELEMENTS

MSC OUTPUT

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	1.488159E-02	0.0	1.297565E-02	0.0
2	G	0.0	0.0	1.623873E-02	3.260004E-02	6.302241E-03	1.105459E-03
3	G	0.0	0.0	1.949219E-02	1.259453E-01	-8.333838E-03	-7.068854E-04
4	G	0.0	0.0	2.214893E-02	1.881285E-01	-2.981238E-02	-1.720419E-03
5	G	0.0	0.0	2.044334E-02	2.376534E-01	-5.672706E-02	-2.624311E-03
6	G	0.0	0.0	[illegible].512377E-03	2.705136E-01	-8.735808E-02	-3.386547E-03
7	G	0.0	0.0	-1.639316E-02	2.789256E-01	-1.191964E-01	-3.942670E-03
8	G	0.0	0.0	-6.364493E-02	2.570521E-01	-1.489690E-01	-4.086468E-03
9	G	0.0	0.0	-1.389790E-01	0.0	-1.634467E-01	-5.355548E-03
10	G	4.370032E-02	0.0	1.402224E-02	0.0	1.071695E-02	0.0
11	G	2.754780E-02	-3.231469E-03	1.615973E-02	7.232695E-02	7.423943E-03	1.472248E-02
12	G	-1.543843E-02	-3.879277E-03	1.929014E-02	1.160193E-01	-5.489751E-03	2.558849E-02
13	G	-7.970110E-02	1.803154E-04	2.183047E-02	1.517092E-01	-2.534725E-02	3.470046E-02
14	G	-1.612722E-01	1.063959E-02	2.010849E-02	1.739005E-01	-5.067214E-02	4.208433E-02
15	G	-2.551457E-01	2.877427E-02	9.386890E-03	1.803120E-01	-7.968822E-02	4.696886E-02
16	G	-3.542117E-01	5.529228E-02	-1.587797E-02	1.691137E-01	-1.102678E-01	4.829599E-02
17	G	-4.492348E-01	9.010967E-02	-6.169318E-02	1.497871E-01	-1.404172E-01	4.528507E-02
18	G	-5.294844E-01	1.320778E-01	-1.340410E-01	0.0	-1.630579E-01	3.724567E-02
19	G	8.300618E-02	0.0	1.472343E-02	0.0	7.897929E-03	0.0
20	G	5.366356E-02	-6.061701E-03	1.586366E-02	7.629420E-02	6.358043E-03	2.677065E-02
21	G	-2.822683E-02	-7.221833E-03	1.855773E-02	1.131810E-01	-4.757439E-03	4.851977E-02
22	G	-1.528755E-01	7.142373E-04	2.063585E-02	1.418970E-01	-2.264605E-02	6.542760E-02
23	G	-3.112799E-01	2.108605E-02	1.870670E-02	1.575670E-01	-4.568077E-02	8.038319E-02
24	G	-4.927777E-01	5.631252E-02	8.427706E-03	1.589888E-01	-7.203154E-02	8.939063E-02
25	G	-6.840820E-01	1.076638E-01	-1.516993E-02	1.496903E-01	-9.991183E-02	9.246780E-02
26	G	-8.704751E-01	1.750302E-01	-5.732376E-02	1.383166E-01	-1.280042E-01	8.974052E-02
27	G	-1.039088E+00	2.569164E-01	-1.232866E-01	0.0	-1.501012E-01	8.310465E-02
28	G	1.152777E-01	0.0	1.413831E-02	0.0	5.148641E-03	0.0
29	G	7.472901E-02	-8.300558E-03	1.498932E-02	8.993725E-02	4.714099E-03	3.693191E-02
30	G	-4.067949E-02	-9.711580E-03	1.706040E-02	1.168659E-01	-4.884850E-03	6.647274E-02
31	G	-2.185333E-01	1.802567E-03	1.848873E-02	1.369650E-01	-2.031904E-02	9.453129E-02
32	G	-4.450763E-01	3.107015E-02	1.634832E-02	1.457215E-01	-4.025970E-02	1.144196E-01
33	G	-7.041574E-01	8.151313E-02	6.915911E-03	1.424343E-01	-6.306400E-02	1.271481E-01
34	G	-9.774102E-01	1.549098E-01	-1.401832E-02	1.303859E-01	-8.721155E-02	1.322146E-01
35	G	-1.246591E+00	2.512781E-01	-5.088077E-02	1.166845E-01	-1.116734E-01	1.306890E-01
36	G	-1.496247E+00	3.690781E-01	-1.081577E-01	0.0	-1.313339E-01	1.261592E-01
37	G	1.395788E-01	0.0	1.285421E-02	0.0	2.296834E-03	0.0
38	G	8.994594E-02	-9.909747E-03	1.337338E-02	9.763631E-02	3.088094E-03	4.519776E-02
39	G	-5.298783E-02	-1.131881E-02	1.476189E-02	1.140346E-01	-4.611195E-03	8.497571E-02
40	G	-2.751050E-01	3.339947E-03	1.553642E-02	1.257372E-01	-1.706274E-02	1.180168E-01
41	G	-5.587978E-01	4.016229E-02	1.334898E-02	1.281200E-01	-3.329806E-02	1.430467E-01
42	G	-8.832884E-01	1.034509E-01	5.196754E-03	1.209811E-01	-5.198572E-02	1.590799E-01
43	G	-1.226153E+00	1.954803E-01	-1.231892E-02	1.083166E-01	-7.191026E-02	1.661673E-01

PROBLEM 12 COMPOSITE SHELL ROOF - CTRIA3 ELEMENTS

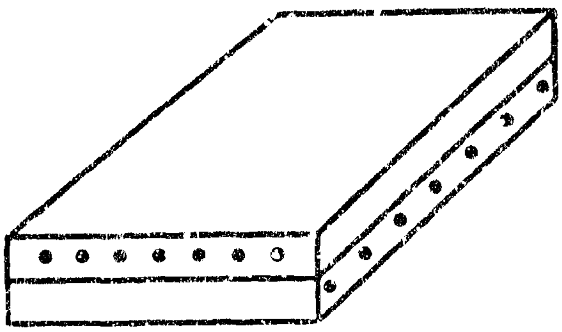
MSC OUTPUT (CONTD)

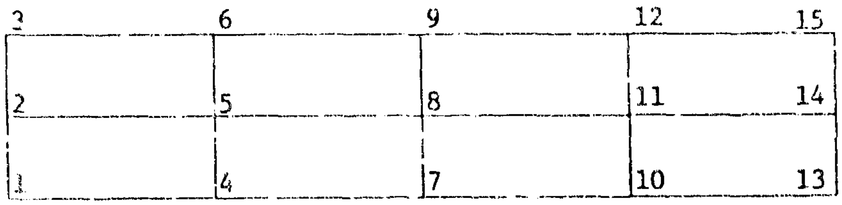
44	G	-1.566740E+00	3.164809E-01	-4.276921E-02	9.[illegible]392E-02	-9.238200E-02	1.662851E-01
45	G	-1.891454E+00	4.650046E-01	-8.977510E-02	0.0	-1.090747E-01	1.641039E-01
46	G	1.557078E-01	0.0	1.079951E-02	0.0	-3.798279E-04	0.0
47	G	9.953328E-02	-1.091489E-02	1.099804E-02	9.500884E-02	1.645601E-03	5.121743E-02
48	G	-6.400058E-02	-1.213516E-02	1.174218E-02	1.101552E-01	-3.827984E-03	9.748330E-02
49	G	-3.203450E-01	5.092703E-03	1.198581E-02	1.145105E-01	-1.322398E-02	1.363789E-01
50	G	-6.491657E-01	4.790815E-02	9.996753E-03	1.098994E-01	-2.567515E-02	1.657968E-01
51	G	-1.025912E+00	1.213806E-01	3.505278E-03	9.835787E-02	-4.009001E-02	1.847004E-01
52	G	-1.424911E+00	2.282475E-01	-1.005018E-02	8.471708E-02	-5.555328E-02	1.936597E-01
53	G	-1.823768E+00	3.689791E-01	-3.337160E-02	7.237545E-02	-7.145791E-02	1.954772E-01
54	G	-2.208994E+00	5.422893E-01	-6.911366E-02	0.0	-8.449339E-02	1.955358E-01
55	G	1.651378E-01	0.0	8.004886E-03	0.0	-1.534491E-03	0.0
56	G	1.050687E-01	-1.140391E-02	7.865760E-03	1.161919E-01	1.292911E-03	5.495435E-02
57	G	-7.231621E-02	-1.237000E-02	8.075285E-03	1.011229E-01	-2.874816E-03	1.062388E-01
58	G	-3.530846E-01	6.719551E-03	8.021737E-03	9.764549E-02	-9.239995E-03	1.496353E-01
59	G	-7.149160E-01	5.385436E-02	6.520945E-03	8.794370E-02	-1.782336E-02	1.824604E-01
60	G	-1.130271E+00	1.347380E-01	1.996592E-03	7.388631E-02	-2.777240E-02	2.035848E-01
61	G	-1.571003E+00	2.524819E-01	-7.286683E-03	5.962552E-02	-3.835132E-02	2.141181E-01
62	G	-2.013773E+00	4.077701E-01	-2.306932E-02	5.969225E-02	-4.963985E-02	2.175228E-01
63	G	-2.445431E+00	5.995078E-01	-4.706422E-02	0.0	-5.927353E-02	2.197395E-01
64	G	1.658712E-01	0.0	4.412975E-03	0.0	-5.981099E-03	0.0
65	G	1.067296E-01	-1.143024E-02	4.039316E-03	7.359419E-02	-2.180564E-04	5.660340E-02
66	G	-7.722476E-02	-1.227560E-02	4.021035E-03	1.047540E-01	-1.248734E-03	1.105871E-01
67	G	-3.726837E-01	7.833988E-03	3.947961E-03	9.417622E-02	-5.160896E-03	1.580029E-01
68	G	-7.564764E-01	5.757254E-02	3.136728E-03	7.860163E-02	-1.075205E-02	1.936642E-01
69	G	-1.197937E+00	1.431109E-01	7.645905E-04	5.680722E-02	-1.726504E-02	2.163565E-01
70	G	-1.666436E+00	2.677848E-01	-4.036724E-03	3.941693E-02	-2.394976E-02	2.277070E-01
71	G	-2.137921E+00	4.323893E-01	-1.207806E-02	1.250840E-02	-2.978623E-02	2.323784E-01
72	G	-2.600875E+00	6.360321E-01	-2.400697E-02	0.0	-3.367934E-02	2.367507E-01
73	G	1.609050E-01	0.0	0.0	-1.104910E-01	0.0	0.0
74	G	1.037114E-01	-1.149914E-02	0.0	2.032132E-01	0.0	5.624982E-02
75	G	-7.952528E-02	-1.232689E-02	0.0	1.294580E-01	0.0	1.141604E-01
76	G	-3.810907E-01	8.167893E-03	0.0	1.086516E-01	0.0	1.633870E-01
77	G	-7.748047E-01	5.900292E-02	0.0	7.534010E-02	0.0	2.004330E-01
78	G	-1.228686E+00	1.465074E-01	0.0	4.785991E-02	0.0	2.238440E-01
79	G	-1.710430E+00	2.740414E-01	0.0	2.020216E-02	0.0	2.351301E-01
80	G	-2.194278E+00	4.422544E-01	0.0	8.441722E-02	0.0	2.411606E-01
81	G	-2.673986E+00	6.502062E-01	0.0	-2.788148E-01	0.0	2.413830E-01
5001	G	0.0	0.0	0.0	0.0	0.0	0.0

Appendix F: NASTRAN Input and Output for Problem #15

PROBLEM #15

COMPOSITE RECTANGULAR PLATE - UNSYMMETRIC CROSS-PLY LAMINATE





UNSYMMETRIC
CROSS-PLY LAMINATE

FIGURE A1

One half of a composite rectangular plate modeled with the unsymmetric cross-ply layup (0°, 90°) is shown in Fig. A1. The plate is modeled with 15 nodes and 8 elements. The length of the plate is 5", the width is 1", and the thickness of each layer is .005". The material properties matrix on the MAT2 card is given as $G_{11} = 1.94x10^7$, $G_{12} = 4.66x10^5$, $G_{22} = 1.33x10^5$ and $G_{33} = 8.3x10^5$. The thermal expansion coefficient vector is defined by $A_1 = -1x10^{-6}$ $A_2 = 15x10^{-6}$ and $A_{12} = 0$. A temperature field was defined for the plate by an average temperature of 230° over the cross-section of each element on the TEMPP1 card. The input data, the calculated thermal loading, and the displacements due to the thermal loading are also provided.

PROBLEM 15

```
ID PLATE,SANDHU
APP DISP
SOL 1
TIME 5
CEND
 TEST PLATE FOR THERMAL LOAD FOR SANDHU                                  APRIL   6, 1992  CSA/NASTRAN  3/31/91

                              C A S E   C O N T R O L   D E C K   E C H O

          CARD
          COUNT
           1       TITLE = TEST PLATE FOR THERMAL LOAD FOR SANDHU
           2       SPC = 16
           3       SPCFORCES = ALL
           4       OLOAD = ALL
           5       DISP(PRINT,PUNCH) = ALL
           6       STRESS = ALL
           7       SUBCASE 1
           8       TEMP(LOAD) = 100
           9       BEGIN BULK
                 TOTAL INPUT BULK DATA CARD COUNT BETWEEN BEGIN BULK AND ENDDATA =        31
                                    TOTAL NUMBER OF BULK DATA CARDS PROCESSED =        32
 TEST PLATE FOR THERMAL LOAD FOR SANDHU                                  APRIL   6, 1992  CSA/NASTRAN  3/31/91

                                   S O R T E D   B U L K   D A T A   E C H O

          CARD
          COUNT        .   1  ..  2  ..  3  ..  4  ..  5  ..  6  ..  7  ..  8  ..  9  ..  0  .
            1-       CQUAD4  1       10001   1       4       5       2       0.0
            2-       CQUAD4  2       10001   2       5       6       3       0.0
            3-       CQUAD4  3       10001   4       7       8       5       0.0
            4-       CQUAD4  4       10001   5       8       9       6       0.0
            5-       CQUAD4  5       10001   7       10      11      8       0.0
            6-       CQUAD4  6       10001   8       11      12      9       0.0
            7-       CQUAD4  7       10001   10      13      14      11      0.0
            8-       CQUAD4  8       10001   11      14      15      12      0.0
            9-       GRID    1               0.0     0.0     0.0
           10-       GRID    2               0.0     .50     0.0
           11-       GRID    3               0.0     1.0     0.0
           12-       GRID    4               1.25    0.0     0.0
           13-       GRID    5               1.25    .50     0.0
           14-       GRID    6               1.25    1.0     0.0
           15-       GRID    7               2.50    0.0     0.0
           16-       GRID    8               2.50    .50     0.0
           17-       GRID    9               2.50    1.0     0.0
           18-       GRID    10              3.75    0.0     0.0
           19-       GRID    11              3.75    .50     0.0
           20-       GRID    12              3.75    1.0     0.0
```

```
21-     GRID     13                 5.0      0.0      0.0
22-     GRID     14                 5.0      .50      0.0
23-     GRID     15                 5.0      1.0      0.0
24-     MAT2     30001    1.94+7    4.66+5            1.33+6            8.3+5          +DEF
25-     +DEF     -1.-6    15.-6              0.
26-     PCOMP1   10001                       60000.   STRAIN   30001    .01            +ABC
27-     +ABC     0.0      90.
28-     SPC1     16       6         4        THRU     15
29-     SPC1     16       123456    1        THRU     3
30-     TEMPP1   100      1         230.                                               +TPA
31-     +TPA     2        THRU      8
        ENDDATA
```

L O A D   V E C T O R

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	-4.067550E+00	-1.016887E+01	0.0	-2.292381E-01	-9.169525E-02	0.0
2	G	-8.135100E+00	1.705303E-13	0.0	0.0	-1.833905E-01	0.0
3	G	-4.067550E+00	1.016887E+01	0.0	2.292381E-01	-9.169525E-02	0.0
4	G	4.547474E-13	-2.033775E+01	0.0	-4.584762E-01	1.776357E-15	0.0
5	G	0.0	-5.684342E-14	0.0	0.0	4.440892E-16	0.0
6	G	-4.547474E-13	2.033775E+01	0.0	4.584762E-01	-1.776357E-15	0.0
7	G	4.547474E-13	-2.033775E+01	0.0	-4.584762E-01	1.776357E-15	0.0
8	G	0.0	-5.684342E-14	0.0	0.0	4.440892E-16	0.0
9	G	-4.547474E-13	2.033775E+01	0.0	4.584762E-01	-1.776357E-15	0.0
10	G	4.547474E-13	-2.033775E+01	0.0	-4.584762E-01	1.776357E-15	0.0
11	G	0.0	-5.684342E-14	0.0	0.0	4.440892E-16	0.0
12	G	-4.547474E-13	2.033775E+01	0.0	4.584762E-01	-1.776357E-15	0.0
13	G	4.067550E+00	-1.016888E+01	0.0	-2.292381E-01	9.169525E-02	0.0
14	G	8.135100E+00	-2.273737E-13	0.0	0.0	1.833905E-01	0.0
15	G	4.067550E+00	1.016888E+01	0.0	2.292381E-01	9.169525E-02	0.0

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

POINT ID.	TYPE	T1	T2	T3	R1	R2	R3
1	G	0.0	0.0	0.0	0.0	0.0	0.0
2	G	0.0	0.0	0.0	0.0	0.0	0.0
3	G	0.0	0.0	0.0	0.0	0.0	0.0
4	G	8.282617E-04	-3.794536E-04	-1.075627E-01	-8.041327E-02	1.728277E-01	0.0
5	G	9.649792E-04	-1.712008E-12	-1.275678E-01	2.652152E-11	2.033811E-01	0.0
6	G	8.282617E-04	3.794536E-04	-1.075627E-01	8.041327E-02	1.728277E-01	0.0
7	G	1.853320E-03	-3.837750E-04	-4.625432E-01	-8.305494E-02	3.947364E-01	0.0
8	G	1.727469E-03	-7.303463E-12	-4.833479E-01	1.825518E-11	3.662719E-01	0.0
9	G	1.853320E-03	3.837749E-04	-4.625432E-01	8.305494E-02	3.947364E-01	0.0
10	G	2.633011E-03	-3.380588E-04	-1.059582E+00	-7.217816E-02	5.607316E-01	0.0
11	G	2.736763E-03	-1.580492E-11	-1.077608E+00	1.8140[illegible]	5.843386E-01	0.0
12	G	2.633011E-03	3.380588E-04	-1.059582E+00	7.217816E-02	5.607316E-01	0.0
13	G	3.624009E-03	-3.709266E-04	-1.894176E+00	-7.982263E-02	7.745631E-01	0.0
14	G	3.534427E-03	-3.137500E-11	-1.914137E+00	-4.224974E-10	7.541634E-01	0.0
15	G	3.624009E-03	3.709265E-04	-1.894176E+00	7.982263E-02	7.745631E-01	0.0

ORIGINAL & DEFORMED PLATE