SKIN-STRINGER PANEL NORMAL MODE RESPONSE
EXPERIMENTAL DATA AND FINITE ELEMENT
COMPUTER PROGRAM DOCUMENTATION

A Supplement to "Study of Effects of Design
Details on Structural Response to Acoustic
Excitation," NASA CR-1959

by

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SUMMARY

This report contains the detail information for the analytical and the experimental programs described in the report "Study of Effects of Design Details on Structural Response to Acoustic Excitation," NASA CR-1959 (reference 1) and is intended as a supplement to that report. Since this report is a supplement the contents of reference 1 are continuously quoted, and the reader must refer to the original text for complete continuity.

INTRODUCTION

The analytical and experimental program described in reference 1 was concerned with the application of the finite element displacement method for the prediction of displacements and strain distributions for the normal mode vibration of flat stiffened panels. Panels with stiffeners in one direction (one dimensional panels) and panels with orthogonal stiffening (two-dimensional panels) were considered. Details of the stiffener and its attachment to the plate were taken into account. In the case of the one-dimensional panel, elastic edge conditions on the boundary along the panel width were considered analytically. The material presented in reference 1 is essentially a summary of the analytical approach and the experimental results, and this report provides essential documentation for persons interested in more detailed information.

The stiffness and consistent mass matrix for both the stiffener model and the plate element developed in reference 1 is discussed and presented in detail in the appendix. An outline of the computer programs is presented along with pertinent details of the analysis. Detailed experimental data from all the specimens described in reference 1 is discussed and presented in tabulated form.
ANALYTICAL PROGRAM

One aspect of the analytical program described in reference 1 considered the derivation of a beam element to represent a thin-walled open-section stiffener as is usually encountered in aircraft structure. This element was used to model the stiffeners for the panel configurations under consideration. For the one-dimensional panel configuration, the stiffener warping coordinate was taken to be zero since warping is an odd function along the stiffener length and is zero at the panel centerline for the assumed fundamental mode in the direction of the stiffener (see equations 20a and 20b, reference 1). For the two-dimensional panel analysis the stiffener warping coordinate was taken equal to the panel twist to insure compatibility of slope between the stiffener element and the plate element. The two-dimensional panel configuration required consideration of a coordinate transformation to describe stiffeners parallel to the x-axis and the y-axis, and since it was necessary to consider rotation of the stiffener about a general point on the stiffener profile line (the 'attach' point), it was also necessary to develop transformations for the elastic forces from the shear center to the attach point and for the inertia forces from the centroid to the attach point (equations 10 through 13, reference 1). All of these transformations have been carried out and are summarized as a composite stiffness and mass matrix for the stiffener element. The adjective 'composite' is used to denote the use of logic numbers to compute the stiffness or the mass matrix for a stiffener parallel to the x-axis or the y-axis. The composite stiffness and mass matrices are presented in Appendix A. The notation and the sign conventions are as described in reference 1.

The rectangular plate bending element described in reference 1 was based upon the 16 degree-of-freedom plate bending element described by Bogner, Fox, and Schmidt (reference 2). The modification introduced in reference 1 was to consider an internal mode for the element in the form of clamped-clamped beam functions described by the coordinate \( W \) (equation 23, ref. 1). The introduction of the coordinate \( W \) resulted in the definition of modifying terms for the basic stiffness and mass matrices. These modifying terms (equations 26 and 27, ref. 1) are presented in Appendix B. The notation and sign convention are as described in reference 1.

COMPUTER PROGRAMS

The basic computer program flow chart for the one-dimensional panel analysis is presented in figure 1. The program computes, sequentially, the element properties for a
bay of structure and assembles the element in the free-free stiffness and mass matrices by application of displacement compatibility and equilibrium conditions at each element node. The desired elastic supports are assembled in the free-free stiffness and mass matrices introducing the elastic constraints. If a lumped mass is desired, the data is introduced as a lumped support with zero stiffness. The stiffness and mass matrices are non-dimensionalized, and kinematic constraints are applied at either end of the structure as desired. The kinematic constraint is of the form of a clamped support at either or both ends of the structure and is realized computationally by deleting the row-column terms in the stiffness and mass matrices corresponding to the constrained coordinates and appropriately reordering the stiffness and mass matrices. The eigenvalue problem is formulated and the eigenvalues and eigenvectors are obtained using standard routines (reference 3) based upon the Jacobi's method (reference 4). The non-dimensionalizing parameters and the eigenvalues and corresponding eigenvectors are printed. If mode shapes, shear, and bending moment distributions are desired, the values are computed, normalized to the maximum value, and printed. Values for the displacement, shear, and bending moment for points interior to an element are computed using equations 16, 17, and 18 of reference 1.

The basic flow chart for the two-dimensional panel computer program is presented in figure 2. The program computes the system stiffness characteristics, non-dimensionalizes the matrix, removes the constrained coordinates (clamped-edges), and reassembles the stiffness matrix. The plate stiffness is computed first and then the rib stiffness is computed. Each element is introduced into the free-free system by applying displacement compatibility and equilibrium conditions at each grid point. The consistent mass matrix is assembled identically to the stiffness matrix, the eigenvalue problem is formulated, and the eigenvalues and eigenvectors are obtained as previously described. Figure 3 illustrates the stiffened plate in plan view showing the bay (plate element) and the rib nomenclature. The plate stiffness and mass matrices are assembled in the sequence indicated by the plate bay number, and the rib stiffness and mass matrices are assembled in the sequence indicated by the rib number and rib segment number as indicated in figure 3. The assembly of the rib and the plate elements at the intersection of two orthogonal ribs is illustrated in figure 4. The positive coordinate directions are as indicated. Computer program listings, flow charts, and descriptions for the one-dimensional and two-dimensional panel arrays are presented in Appendix C. The necessary information for data input and program output is presented in Appendix D.
EXPERIMENTAL DATA

One of the objectives of the program described in reference 1 was to provide data for comparison with the analytical results. The technique used to determine mode shapes and strain distributions is described in reference 1. Comparison of theory and experiment is given in reference 1 for frequencies, mode shapes, and strain (bending moment) distribution (in the case of one-dimensional panels).

Each specimen was mounted in the test frame and cork particles were sprinkled on the specimen. The specimen was excited by discrete frequency sinusoidal excitation using a specially designed speaker enclosure as described in reference 1. Frequency sweeps were conducted for four speaker phase conditions (ref. 1). The predominant modes as indicated by the Chladni patterns formed by the cork particles were photographed. These patterns, for the indicated specimen, frequency, and speaker phase condition, are presented in Appendix E.

For the one-dimensional panel specimens, mode shapes were determined using two (2) accelerometers. One accelerometer was fixed in position for a reference value and the other accelerometer was stepped in position along the centerline of the panel. At each position of the stepped accelerometer, amplitude and phase of both accelerometers (as observed on an oscilloscope) was recorded. The accelerometer positions for the one-dimensional specimens is given in figure 5. The accelerometers were calibrated to give identical output for a given input, but no attempt was made to force an absolute output since only relative acceleration (displacement) was desired. Data reduction was accomplished by determining the accelerometer output in millivolts for both accelerometers, dividing the value at a position by the reference value for the positions, and then normalizing the set of data to the largest value of the ratio (not necessarily the reference position). The normalized acceleration data (mode shape) for the specimen, the indicated position (figure 5), frequency, and speaker phase conditions are tabulated in Tables 1 through 8. A minus sign as a value indicates a 180° phase shift with respect to the reference value and an asterisk denotes a 90° phase shift. To compare the normalized experimental values with the computed normalized mode shapes, the ratio of the experimental value and the computed value at a point on the structure was determined, all experimental values for the mode were multiplied by this ratio, and the data plotted. The plotted data comparison for the one-dimensional panel specimens is given in figures 22 through 38 of reference 1.
Strain measurements in the direction of the panel length (perpendicular to the ribs) was accomplished by placing fifteen strain gages along the panel as indicated in figure 5. Detailed location of the strain gages is indicated in figure 18 of reference 1. Data reduction for the strain measurements was accomplished as described for the acceleration data. The strain gage system was calibrated so that one millivolt of output corresponded to 417 microinches per inch of strain. Strain gage output in millivolts and phase with the indicated reference is tabulated in Tables 9 through 16 for the indicated specimen, strain gage, frequency, and speaker phase condition. The plotted comparison between the experimental and calculated values for strain are given in figures 22 through 38 of reference 1.

As described in reference 1, experimental determination of mode shapes for the two-dimensional panel specimens was more difficult than for the one-dimensional specimens. A detailed experimental mode investigation was possible only for the machined panel specimen. For specimens SP II-1 and SP II-2, only the basic phase relationship between adjacent panel bays could be determined. Acceleration measurements for the machined panel specimen were taken at the locations illustrated in figure 6. Tabulated values for accelerometer output in millivolts with phase relative to the reference are given in Table 17 for the indicated position, frequency, and speaker phase condition. For the machined panel specimen the strain gage locations are indicated in figure 7 with the exact location indicated by the \((x, y)\) coordinate position given in Table 18.

For specimens SP II-1 and SP II-2 the tabulated values for acceleration in millivolts for the center of each panel bay is given in Table 19. Strain gage location and nomenclature for specimens SP II-1 and SP II-2 are given in figures 8 and 9, respectively, with the exact location tabulated. Strain measurements for the indicated specimen, frequency, and speaker phase condition are given in Tables 20 through 22. The strain gage calibration was such that 417 microinches per inch equaled one millivolt of strain gage output.

Damping was measured for selected strain gages by determining the logarithmic decrement from the photograph of the decaying strain signal (ref. 5). The specimen was excited in a given mode with the selected strain gage signal displayed on an oscilloscope. The excitation was suddenly stopped and the decaying strain signal photographed with a camera mounted on the oscilloscope. The logarithmic decrement and the damping ratio were determined from the photograph. For the indicated specimen, strain gage, and frequency, values of the damping ratio (percent of critical damping) are given in Table 23.
FIGURE 1. FLOW CHART: PROGRAM BMPROP(MAIN)/ONE-DIMENSIONAL PANEL ARRAYS (CONTINUED)
Figure 1. Flow Chart: Program BMPROP(MAIN)/One-Dimensional Panel Arrays (Concluded)
INITIALIZE
GEOMETRIC
PARAMETERS

SEGMENT 1
READ INPUT DATA
RDNWRT (1)

FILL CONSTRAINT VECTOR, NDEL(1)
FOR CLAMPED EDGES
COMPUTE LENGTH PARAMETER, TK
COMPUTE PLATE RIGIDITY, DP

PRINT EDITED
INPUT DATA
RDNWRT (2)

IOP = 1
(STIFFNESS
CALCULATIONS)

IOP = 1, 2

IOP = 2
(MASS
CALCULATIONS)

INITIALIZE
SUPER MATRIX, R
ZERO (R, N)

A

INITIALIZE
SUPER MATRIX, R
ZERO (R, N)

B

FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL
PANEL ARRAYS (CONTINUED)
CALCULATE PLATE STIFFNESS FOR PANEL BAY PLTSTF

ASSEMBLE PARTITIONED PLATE STIFFNESS MATRIX IN SUPER MATRIX, R ASSYP

STEP 5

STEP 6

STEP 7

STEP 8

STEP 9

STEP 10

STEP 11

STEP 12

STEP 13

FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)
FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)
YES

COMPUTE PARTITIONED RIB MASS MATRIX FOR RIB ELEMENT

RIB

ASSEMBLE RIB ELEMENT MATRIX IN SUPER MATRIX, R

ASSYR

HAVE ALL RIBS BEEN CONSIDERED?

YES

NO

STEP 17

STEP 18

STEP 19

STEP 20

STEP 21

STEP 22

STEP 23

FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONTINUED)
FIGURE 2. FLOW CHART: PROGRAM PLTVIB(MAIN)/TWO-DIMENSIONAL PANEL ARRAYS (CONCLUDED)
FIGURE 3. TWO-DIMENSIONAL PANEL GEOMETRY AND ELEMENT NOMENCLATURE

FIGURE 4. PLATE AND RIB ELEMENT ASSEMBLY
FIGURE 5. ACCELEROMETER AND STRAIN GAGE LOCATIONS FOR ONE-DIMENSIONAL PANELS

*Note: Locations not indicated are sequentially spaced at one inch intervals.
FIGURE 6. ACCELEROMETER LOCATION FOR NINE-BAY MACHINED PANEL SPECIMENS
FIGURE 7. STRAIN GAGE LOCATION FOR MACHINED PANEL SPECIMENS (SEE TABLE 18)
SCALE = 1/60

STIFFENERS NOT SHOWN IN PLANVIEW FOR CLARITY

FIGURE 8. STRAIN GAGE LOCATIONS FOR SPECIMEN SPII-1
(SEE TABLE 18)
STIFFENERS NOT SHOWN IN PLANVIEW FOR CLARITY

FIGURE 9. STRAIN GAGE LOCATIONS FOR SPECIMEN SPII-2
(SEE TABLE 18)
TABLE 1

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS:
ONE-DIMENSIONAL PANELS

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*90° Phase shift to reference
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*90° Phase shift to reference.
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*90° Phase shift to reference.
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*90° Phase shift to reference.

T response at twice frequency of reference.
**TABLE 9**

NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

\[ \bar{\varepsilon} = \text{NORMALIZING STRAIN, } \mu \text{ in/in} \]

SPECIMEN SPI-1

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\[ \bar{\varepsilon}, \mu \text{ in/in} \]

63 158 150 250 75 168 208

*90° Phase shift to reference.

T response at twice reference frequency.
TABLE 10
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
$\tilde{\varepsilon} = \text{NORMALIZING STRAIN, } \mu \text{ in/in}$
SPECIMEN SPI-2-1

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*90° Phase shift to reference.
TABLE 11
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION

\( \bar{e} = \text{NORMALIZING STRAIN, } \mu \text{ in/in} \)

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\( \bar{e}, \mu \text{ in/in} \)

| 105 | 125 | 312 | 92 | 125 | 67 | 75 |

*90° Phase shift to reference.
T Response at twice reference frequency.
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*90° Phase shift to reference.
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<td>167</td>
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TABLE 16
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
$\tilde{e} =$ NORMALIZING STRAIN, $\mu$ in/in
SPECIMENS SPI-3-1D AND SPI-3-2D

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<td>-0.47</td>
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<td>-</td>
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*90° Phase shift to reference.
T Response at twice frequency of reference.
### TABLE 17

NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS

NINE-BAY MACHINED PANEL SPECIMEN

(See Figure 6)

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*90° Phase shift to reference.
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*90° Phase shift to reference.
TABLE 18
STRAIN GAGE LOCATIONS
NINE-BAY PANEL SPECIMENS

Machines Panel Specimen
(See Figure 7)

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<td>(13.0, 12.35)</td>
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<td>Y2</td>
<td>(13.0, 16.25)</td>
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<td>Y3</td>
<td>(13.0, 18.3 )</td>
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<td>Y4</td>
<td>(13.0, 19.85)</td>
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<td>Y5</td>
<td>(13.0, 21.85)</td>
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<td>(13.0, 23.75)</td>
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<td>Y7</td>
<td>(13.0, 24.25)</td>
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<td>(16.25, 18.0)</td>
<td>Y8</td>
<td>(13.0, 27.10)</td>
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<td>(19.60, 18.0)</td>
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<tr>
<td>X10</td>
<td>(22.80, 18.0)</td>
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SPII-1
(See Figure 8)

<table>
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<th>SG</th>
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</thead>
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<td>Y1</td>
<td>(13.5, 7.50)</td>
</tr>
<tr>
<td>X2</td>
<td>(8.0 , 18.5)</td>
<td>Y2</td>
<td>(13.5,10.50)</td>
</tr>
<tr>
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<td>(9.0 , 18.5)</td>
<td>Y3</td>
<td>(13.5,11.50)</td>
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<tr>
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<td>(10.75, 18.5)</td>
<td>Y4</td>
<td>(13.5,14.90)</td>
</tr>
<tr>
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<td>(13.5, 18.5)</td>
<td>Y5</td>
<td>(13.5,18.50)</td>
</tr>
<tr>
<td>X6</td>
<td>(15.75, 18.5)</td>
<td>Y6</td>
<td>(13.5,21.90)</td>
</tr>
<tr>
<td>X7</td>
<td>(18.0 , 18.5)</td>
<td>Y7</td>
<td>(13.5,25.50)</td>
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<tr>
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<td>Y8</td>
<td>(13.5,26.50)</td>
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<tr>
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<td>(13.5,30.00)</td>
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SPII-2
(See Figure 9)

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<td>Y1</td>
<td>(13.5, 8.5 )</td>
</tr>
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<td>Y2</td>
<td>(13.5,10.75)</td>
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<tr>
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<td>(9.7 , 18.5)</td>
<td>Y3</td>
<td>(13.5,13.00)</td>
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<tr>
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<td>Y4</td>
<td>(13.5,14.10)</td>
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<td>(13.5, 18.5)</td>
<td>Y5</td>
<td>(13.5,18.5 )</td>
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<td>(13.5,23.0 )</td>
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<td>(13.5,24.0 )</td>
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<td>(13.5,26.25)</td>
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<tr>
<td>X9</td>
<td>(20.1 , 18.5)</td>
<td>Y9</td>
<td>(13.5,28.50)</td>
</tr>
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### TABLE 19
NORMALIZED ACCELERATION (DISPLACEMENT) MEASUREMENTS
NINE-BAY PANEL SPECIMENS SPII-1 AND SPII-2

**Specimen SPII-1**

<table>
<thead>
<tr>
<th>Frequency, Hz</th>
<th>90</th>
<th>97</th>
<th>101</th>
<th>107</th>
<th>112</th>
<th>134</th>
<th>144</th>
<th>168</th>
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<tbody>
<tr>
<td>Bay Number 1</td>
<td>-</td>
<td>0.20</td>
<td>0.23</td>
<td>-0.23</td>
<td>-0.38</td>
<td>-</td>
<td>-0.40</td>
<td>0.70</td>
</tr>
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<td>2</td>
<td>-0.25</td>
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<td>0.30*</td>
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<td>-0.27</td>
<td>0.50</td>
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<td>0.30</td>
<td>-0.19</td>
<td>-0.38</td>
<td>-</td>
<td>0.27</td>
<td>1.00</td>
</tr>
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<td>-1.00</td>
<td>-0.27</td>
<td>0.33</td>
<td>-0.23</td>
<td>-0.38</td>
<td>0.25</td>
<td>0.67</td>
<td>0.65</td>
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<tr>
<td>5</td>
<td>0.19</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.70</td>
<td>-</td>
<td>0.85</td>
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<td>-0.20</td>
<td>-0.27</td>
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<td>-0.54</td>
<td>-0.65</td>
<td>0.27</td>
<td>0.45</td>
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<td>-1.00</td>
<td>-1.00</td>
</tr>
<tr>
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<td>-0.85</td>
<td>-0.23</td>
<td>0.30</td>
<td>0.27</td>
<td>0.31</td>
<td>-0.30</td>
<td>-0.33</td>
<td>-1.00</td>
</tr>
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<td>0.27</td>
<td>0.15</td>
<td>0.38</td>
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<td>0.40</td>
<td>-0.70</td>
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</table>

**Specimen SPII-2**

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<th>112</th>
<th>126</th>
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<td>-</td>
<td>0.15T</td>
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<td>-1.00</td>
<td>0.86</td>
</tr>
<tr>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-0.57</td>
<td>-0.19</td>
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<td>-</td>
</tr>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.27</td>
<td>0.35</td>
</tr>
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</table>

Note: Measurements taken at center of each panel bay.

*90° Phase shift to reference.
TABLE 20
NORMALIZED HALF AMPLITUDE MODAL STRAIN DISTRIBUTION
\( \bar{\varepsilon} = \text{NORMALIZING STRAIN, } \mu\text{in/in} \)
NINE BAY MACHINED PANEL SPECIMEN
(See Table 18 and Figure 7)

<table>
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<th>123/A</th>
<th>148/A</th>
<th>170/A</th>
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<td>-0.80</td>
<td>0.09</td>
<td>0.76</td>
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</tr>
<tr>
<td>X2</td>
<td>0.48</td>
<td>0.40</td>
<td>-0.09</td>
<td>0.00</td>
<td>0.00</td>
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</tr>
<tr>
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<td>-0.80</td>
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<td>0.51</td>
<td>0.00</td>
<td>-0.40</td>
</tr>
<tr>
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<td>-0.51</td>
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<td>-1.00</td>
</tr>
<tr>
<td>X5</td>
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<td>0.80</td>
<td>0.86</td>
<td>0.51</td>
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<td>1.00</td>
</tr>
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<td>0.57</td>
<td>0.25</td>
<td>0.40</td>
<td>0.00</td>
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<tr>
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<td>-1.00</td>
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<tr>
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<td>-0.40</td>
<td>-0.40</td>
</tr>
<tr>
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<td>0.28</td>
<td>0.28</td>
</tr>
<tr>
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<td>-0.51</td>
<td>0.00</td>
<td>-0.61</td>
</tr>
<tr>
<td>Y1</td>
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<td>-0.57</td>
<td>-1.00</td>
<td>0.80</td>
<td>-0.61</td>
</tr>
<tr>
<td>Y2</td>
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<td>0.29</td>
<td>0.51</td>
<td>-0.40</td>
<td>0.61</td>
</tr>
<tr>
<td>Y3</td>
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<td>0.46</td>
<td>0.25</td>
<td>0.61</td>
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<td>Y4</td>
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<td>-0.20</td>
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TABLE 21
NORMALIZED HALF AMPLITUDE MODAL STRAIN DISTRIBUTION
\( \bar{e} = \text{NORMALIZING STRAIN}, \ \mu \text{in/in} \)
NINE BAY PANEL SPECIMEN SPII-1
(See Table 18 and Figure 8)

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TABLE 22
NORMALIZED HALF AMPLITUDE STRAIN DISTRIBUTION
\( \varepsilon = \) NORMALIZING STRAIN, \( \mu \) in/in
NINE BAY PANEL SPECIMEN SPII-2
(See Table 18 and Figure 9)

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<th>81/D</th>
<th>82/A</th>
<th>110/A</th>
<th>112/D</th>
<th>126/B</th>
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<td>0.00</td>
<td>0.00</td>
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<td>0.50</td>
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<td>-0.79</td>
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<td>-0.75</td>
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<td>0.72</td>
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<td>0.40</td>
<td>0.64</td>
<td>0.46</td>
</tr>
<tr>
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<td>1.00</td>
<td>0.72</td>
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<td>0.36</td>
<td>0.52</td>
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<td>0.00</td>
<td>0.64</td>
<td>0.46</td>
</tr>
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<td>0.64</td>
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</tr>
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<td>0.00</td>
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<td>-0.64</td>
<td>0.67</td>
</tr>
<tr>
<td>Y7</td>
<td>-1.00</td>
<td>-0.76</td>
<td>-0.60</td>
<td>0.00</td>
<td>-0.55</td>
<td>0.50</td>
<td>-0.64</td>
<td>-0.67</td>
</tr>
<tr>
<td>Y8</td>
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<td>0.00</td>
<td>-0.50</td>
<td>0.00</td>
<td>0.20</td>
<td>0.50</td>
<td>0.64</td>
<td>0.33</td>
</tr>
<tr>
<td>Y9</td>
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<td>0.00</td>
<td>-0.69</td>
<td>0.00</td>
<td>-0.25</td>
<td>-0.69</td>
<td>-0.76</td>
<td>-0.46</td>
</tr>
</tbody>
</table>

\( \varepsilon \) | 58  | 33  | 42  | 29  | 84  | 42  | 33  | 63  |
TABLE 23
DAMPING RATIOS (PERCENT OF CRITICAL DAMPING)
ONE-DIMENSIONAL PANELS

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Number of Bays</th>
<th>Frequency (Hz)</th>
<th>Strain Gage No.</th>
<th>Damping Ratio (percent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPI-1</td>
<td>5</td>
<td>82</td>
<td>X10</td>
<td>1.1</td>
</tr>
<tr>
<td>SPI-1</td>
<td>5</td>
<td>119</td>
<td>X11</td>
<td>1.3</td>
</tr>
<tr>
<td>SPI-1</td>
<td>5</td>
<td>126</td>
<td>X10</td>
<td>1.3</td>
</tr>
<tr>
<td>SPI-1</td>
<td>3</td>
<td>108</td>
<td>X5/X11</td>
<td>3.0/1.6</td>
</tr>
<tr>
<td>SPI-1</td>
<td>3</td>
<td>127</td>
<td>X11</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>5</td>
<td>88</td>
<td>X8</td>
<td>1.6</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>5</td>
<td>103</td>
<td>X5</td>
<td>2.7</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>5</td>
<td>120</td>
<td>X5</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-1</td>
<td>3</td>
<td>91</td>
<td>X8</td>
<td>3.0</td>
</tr>
<tr>
<td>SPI-2-1D</td>
<td>5</td>
<td>88</td>
<td>X5</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-1D</td>
<td>5</td>
<td>111</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>5</td>
<td>57</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>5</td>
<td>61</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>3</td>
<td>51</td>
<td>X8</td>
<td>2.7</td>
</tr>
<tr>
<td>SPI-2-2</td>
<td>3</td>
<td>61</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-2-1D</td>
<td>5</td>
<td>68</td>
<td>X8</td>
<td>1.5</td>
</tr>
<tr>
<td>SPI-3-1</td>
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<td>80</td>
<td>X5</td>
<td>1.0</td>
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<td>X5</td>
<td>2.9</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>5</td>
<td>107</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>5</td>
<td>117</td>
<td>X5</td>
<td>1.0</td>
</tr>
<tr>
<td>SPI-3-1</td>
<td>3</td>
<td>101</td>
<td>X8</td>
<td>2.0</td>
</tr>
<tr>
<td>SPI-3-2</td>
<td>5</td>
<td>62</td>
<td>X11</td>
<td>1.8</td>
</tr>
<tr>
<td>SPI-3-2</td>
<td>3</td>
<td>68</td>
<td>X8</td>
<td>1.6</td>
</tr>
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<td>SPI-3-2D</td>
<td>5</td>
<td>74</td>
<td>X8</td>
<td>1.6</td>
</tr>
<tr>
<td>SPI-3-2D</td>
<td>3</td>
<td>71</td>
<td>X8</td>
<td>1.5</td>
</tr>
</tbody>
</table>
The stiffness and consistent mass matrices presented here are in the form of a composite array with logic numbers \((\alpha_x, \alpha_y)\) defining terms relating to the orientation of the beam element. Subscripts 1 and 2 in the loading and displacement vectors refer to ends 1 and 2 on the element. End 2 is always in the positive direction of the element axis from end 1. Subscripts \(x\) and \(y\) in the expressions in the matrices refer to the \(x\)-axis and the \(y\)-axis, respectively. The cross-section nomenclature and coordinate directions are defined in figures 3 and 4 of reference 1.

For stiffener elements conforming to the edge rotations of the plate element described in Appendix B, the loading and displacement coordinates at station \(i\) of the element are defined as

\[
\{\bar{P}\}_i = \begin{bmatrix} P \\ M_x \\ M_y \\ M_{xy} \end{bmatrix}_i = \begin{bmatrix} \text{shear in the } z \text{ direction} \\ \text{bending moment about the } x\text{-axis} \\ \text{bending moment about the } y\text{-axis} \\ \text{twisting moment} \end{bmatrix}_i
\]

\[
\{\bar{d}\}_i = \begin{bmatrix} d \\ \theta_x \\ \theta_y \\ \theta_{xy} \end{bmatrix}_i = \begin{bmatrix} \text{displacement in the } z \text{ direction} \\ \text{rotation about the } x\text{-axis} \\ \text{rotation about the } y\text{-axis} \\ \text{twist} \end{bmatrix}_i
\]

The composite beam stiffness matrix has the form

\[
\{\bar{P}\}_1 = [K_{11}][\bar{d}]_1 + [K_{12}][\bar{d}]_2
\]

\[
\{\bar{P}\}_2 = [K_{12}]^T[\bar{d}]_1 + [K_{22}][\bar{d}]_2
\]
where, for ribs parallel to the x-axis \((\alpha_x = 1; \alpha_y = 0)\) and for ribs parallel to the y-axis \((\alpha_x = 0; \alpha_y = 1)\)

\[
[K_{xx}] = \alpha_x [K_{xx}] + \alpha_y [K_{yy}]
\]

\[
[K_{11}]_x = \begin{bmatrix}
12\beta_{yy} & -12R & -6\beta_{y}L & -6\tau_1L \\
-12R & 12\tau_1 & 6R_L & 6\tau_2 \\
6\beta_{y}L & -6R_L & 4\beta_{yy}L & 4\tau_2L \\
6\tau_1L & 6\tau_2 & 4\tau_2L & 4\gamma_3
\end{bmatrix}
\]

\[
[K_{12}]_x = \begin{bmatrix}
-12\beta_{yy} & 12R & -6\beta_{y}L & -6\tau_1L \\
12R & -12\tau_1 & 6R_L & 6\tau_2 \\
6\beta_{y}L & -6R_L & 2\beta_{yy}L & 2\tau_2L \\
6\tau_1L & 2\tau_2L & 2\gamma_3 & 2\gamma_4
\end{bmatrix}
\]

\[
[K_{22}]_x = \begin{bmatrix}
12\beta_{yy} & -12R & 6\beta_{y}L & 6\tau_1L \\
-12R & 12\tau_1 & -6R_L & -6\tau_2 \\
6\beta_{y}L & 4\beta_{yy}L & 4\tau_2L & 4\gamma_3 \\
6\tau_1L & 4\tau_2L & 4\gamma_3 & 4\gamma_3
\end{bmatrix}
\]

\[
[K_{11}]_y = \begin{bmatrix}
12\beta_{xx} & 6\beta_{xy} & 12R & 6\tau_1L \\
6\beta_{xy} & 4\beta_{yx} & 6R_L & 4\tau_2L \\
12\tau_1 & 4\tau_2 & 4\gamma_3 & -6\tau_2 \\
12\tau_1 & 4\gamma_3 & 4\gamma_3 & 4\gamma_3
\end{bmatrix}
\]
Appendix A

\[ [K_{12}]_y = \begin{bmatrix}
-12B_{xx} & 6B_{xx} & -12R_x & 6r L_y \\
-6B_{xx} & 2B_{xx} & -6R_x & 2r L^2_y \\
-12R_x & 6R_x & -12\tau_1 & -6\tau_2 \\
-6r L_y & 2r L^2_y & 6\tau_2 & 2\gamma_4
\end{bmatrix} \]

\[ [K_{22}]_y = \begin{bmatrix}
12B_{xx} & -6B_{xx} & 12R_x & -6r L_y \\
4B_{xx} & -6r L_y & 4r L^2_y & 6r L_y \\
& & 12\tau_1 & 6\tau_2 \\
& & & 4\gamma_3
\end{bmatrix} \text{ (symmetric)} \]

\[ \beta_{ij} = \frac{EI_{ij}/L^3}{ij} \]

\[ r_i = \frac{ER_{ei}/L^3}{i} \]

\[ \gamma_1 = \frac{Eh/L^3 + GJ/10L}{1} \]

\[ \gamma_2 = \frac{Eh/L^2 + GJ/60}{2} \]

\[ \gamma_3 = \frac{Eh/L + GJ/30}{3} \]

\[ \gamma_4 = \frac{Eh/L - GJ/60}{4} \]

for ribs parallel to the \( x \)-axis

\[ \tau_1 = \gamma_1 + S^2_{xx} - 2S_x S_y + S^2_{yy} - 2(S_{xz} - S_{yz})L \]

\[ \tau_2 = \gamma_2 - (S_{x} - S_{r_{z}})L \]

for ribs parallel to the \( y \)-axis

\[ \tau_1 = \gamma_1 + S^2_{zz} - 2S_z S_y + S^2_{yy} - 2(S_{xz} - S_{yz})L \]

\[ \tau_2 = \gamma_2 - (S_{x} - S_{r_{z}})L \]

The composite beam mass matrix has the form

\[ \{\ddot{p}\}_1 = [M_{11}]\{\ddot{a}\} + [M_{12}]\{\ddot{a}\}_2 \]
\[
\{ \bar{P} \}_2 = [M_{12}]^T \{ \bar{d} \}_1 + [M_{22}] \{ \bar{d} \}_2
\]

where \([M_{ij}] = \alpha_i [K_{ij}] + \alpha_j [K_{ij}]\)

\[
[M_{11}]_x = M
\]

\[
\begin{bmatrix}
13/35 & 13e /35 & -11L_x /210 & 0 \\
13L^2 /35 & -11e L_x /210 & 11L^2_{1*}/210 & 0 \\
\end{bmatrix}
\]

(symmetric)

\[
[M_{12}]_x = M
\]

\[
\begin{bmatrix}
9/70 & 9e /70 & 13L_x /420 & 0 \\
9e /70 & 13L^2 /420 & -13e L_x /420 & -13L^2_{1*}/420 \\
-13L_x /420 & -13e L_x /420 & 0 & 0 \\
0 & -13L^3_{1*}/420 & 0 & -13L^4_{1*}/420 \\
\end{bmatrix}
\]

\[
[M_{22}]_x = M
\]

\[
\begin{bmatrix}
13/35 & 13e /35 & -13e L_x /210 & 0 \\
13L^2 /35 & -13e L_x /210 & 13L^2_{1*}/210 & 0 \\
\end{bmatrix}
\]

(symmetric)

\[
[M_{11}]_y = M
\]

\[
\begin{bmatrix}
13/35 & 11L_y /210 & -13e /35 & 0 \\
13L^2 /105 & -11e L_y /210 & 0 & 0 \\
\end{bmatrix}
\]

(symmetric)
\[
\begin{bmatrix}
9/70 & -13L/420 & -9e/L/70 & 0 \\
13L/420 & -L^2/140 & -13e/L_x/420 & 0 \\
-9e/L_x/70 & 13e/L_y/420 & 9L^2/L_y/70 & 13L^3/L_y^*/420 \\
0 & 0 & -13L^3/L_y^*/420 & -L^4/L_y^*/140 \\
\end{bmatrix}
\]

\[
\begin{bmatrix}
13/35 & -11L/210 & -13e/L_x/35 & 0 \\
L^2/105 & 11e/L_y/210 & 13L^2/L_y^*/35 & 11L^3/L_y^*/210 \\
\end{bmatrix}
\]

(symmetric)

For ribs parallel to the x-axis

\[
M = \rho A L_x x_x \quad e_x = C_x - S_x \quad e_z = C_z - S_z \\
2 \gamma = (e_y^2 + e_z^2)/L_x^2 \\
I^*_p = (I_{yy} + I_{zz})/(A x_x^2) \\
I_p = 2 + I^*_p
\]

and for ribs parallel to the y-axis

\[
M = \rho A L_y y_y \quad e_y = C_y - S_y \quad e_z = C_z - S_z \\
2 \gamma = (e_x^2 + e_z^2)/L_y^2 \\
I^*_p = (I_{xx} + I_{zz})/(A y_y^2) \\
I_p = 2 + I^*_p
\]
APPENDIX B

STIFFNESS AND CONSISTENT MASS MATRIX FOR INCLUDING THE FUNDAMENTAL INTERIOR MODE FOR A RECTANGULAR PLATE BENDING ELEMENT

The stiffness and consistent mass matrix presented here are based upon equations (26) and (27) as described in the main text. The basic stiffness matrix is a sixteen-degree-of-freedom element as referenced in the main text, and the modifying interior mode functions are taken as the eigenfunctions for a clamped-clamped beam. The positive coordinate directions for this element are given in figure 9.

At each corner of the element, the loading and displacement coordinates for the ith corner are

\[
\{ \bar{P} \}_i = \begin{bmatrix}
P \\
M_x \\
M_y \\
M_{xy}
\end{bmatrix},
\{ \bar{d} \}_i = \begin{bmatrix}
d \\
\theta_x \\
\theta_y \\
\theta_{xy}
\end{bmatrix}
\]

where \( P \) is the generalized force in the direction.

From equation (26), the stiffness matrix has the form

\[
\frac{\{ \bar{P} \}_i}{P_o} = D \frac{ab}{k} \begin{bmatrix}
K_{ii}^T & K_{ij} \\
K_{ji} & K_{jj}
\end{bmatrix} \begin{bmatrix}
{\bar{d}}_i \\
{\bar{w}}_o
\end{bmatrix},
\]

where \( P_o \) is the generalized force in the \( W_o \) direction. The matrix \([\bar{K}_{ij}]\) has the form

\[
[\bar{K}_{ij}] = \begin{bmatrix}
\bar{K}_{11} & \bar{K}_{12} & \bar{K}_{13} & \bar{K}_{14} \\
\bar{K}_{21} & \bar{K}_{22} & \bar{K}_{23} & \bar{K}_{24} \\
\bar{K}_{31} & \bar{K}_{32} & \bar{K}_{33} & \bar{K}_{34} \\
\bar{K}_{41} & \bar{K}_{42} & \bar{K}_{43} & \bar{K}_{44}
\end{bmatrix}
\]

and is symmetric.
where

\[
\begin{align*}
\begin{bmatrix}
\bar{K}_{11} \end{bmatrix} &=
\begin{bmatrix}
\frac{k}{16} & \frac{kb}{64} & -\frac{ka}{64} & 8k_1a_b \\
\frac{kb^2}{256} & -\frac{ka}{64} & 2k_1a_b^2 \\
\frac{ka^2}{256} & -2k_1a^2_b & k_2a^2_b^2
\end{bmatrix} \\
\text{(symmetric)}
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
\bar{K}_{12} \end{bmatrix} &=
\begin{bmatrix}
\frac{k}{16} & \frac{kb}{64} & \frac{ka}{64} & -8k_1a_b \\
\frac{kb}{64} & \frac{kb^2}{256} & \frac{ka}{64} & -2k_1a_b^2 \\
-\frac{ka}{64} & -\frac{ka}{64} & \frac{ka^2}{256} & 2k_1a^2_b \\
8k_1a_b & 2k_1a_b^2 & 2k_1a^2_b & -k_2a^2_b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
\bar{K}_{13} \end{bmatrix} &=
\begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & -\frac{ka}{64} & -8k_1a_b \\
\frac{kb}{64} & -\frac{kb^2}{256} & -\frac{ka}{64} & -2k_1a_b^2 \\
-\frac{ka}{64} & \frac{ka}{64} & \frac{ka^2}{256} & 2k_1a^2_b \\
8k_1a_b & -2k_1a_b^2 & -2k_1a^2_b & -k_2a^2_b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
\bar{K}_{14} \end{bmatrix} &=
\begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & \frac{ka}{64} & 8k_1a_b \\
\frac{kb}{64} & -\frac{kb^2}{256} & \frac{ka}{64} & 2k_1a_b^2 \\
-\frac{ka}{64} & \frac{ka}{64} & -\frac{ka^2}{256} & -2k_1a^2_b \\
8k_1a_b & -2k_1a_b^2 & 2k_1a^2_b & k_2a^2_b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
\begin{bmatrix}
\bar{K}_{22} \end{bmatrix} &=
\begin{bmatrix}
\frac{k}{16} & \frac{kb}{64} & \frac{ka}{64} & -8k_1a_b \\
\frac{kb^2}{256} & \frac{ka}{64} & -2k_1a_b^2 & -2k_1a^2_b \\
\frac{ka^2}{256} & -2k_1a^2_b & k_2a^2_b^2
\end{bmatrix} \\
\text{(symmetric)}
\end{align*}
\]
\[
\begin{align*}
[\mathbf{K}_{23}] &= \\
&= \begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & -\frac{ka}{64} & -8k_1ab \\
\frac{kb}{64} & -\frac{kb^2}{256} & -\frac{kab}{256} & -2k_1ab^2 \\
\frac{ka}{64} & -\frac{kab}{256} & -\frac{ka^2}{256} & -2k_1a^2b \\
-8k_1ab & 2k_1ab^2 & 2k_1a^2b & k_2a^2b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
[\mathbf{K}_{24}] &= \\
&= \begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & \frac{ka}{64} & 8k_1ab \\
\frac{kb}{64} & -\frac{kb^2}{256} & \frac{kab}{256} & 2k_1a^2b \\
\frac{ka}{64} & -\frac{kab}{256} & \frac{ka^2}{256} & 2k_1ab^2 \\
-8k_1ab & 2k_1ab^2 & -2k_1a^2b & -k_2a^2b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
[\mathbf{K}_{33}] &= \\
&= \begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & -\frac{ka}{64} & -8k_1ab \\
\frac{kb^2}{256} & \frac{kab}{256} & \frac{ka^2}{256} & 2k_1ab^2 \\
(symmetric) & \frac{ka^2}{256} & 2k_1a^2b & k_2a^2b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
[\mathbf{K}_{34}] &= \\
&= \begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & \frac{ka}{64} & 8k_1ab \\
-\frac{kb}{64} & \frac{kb^2}{256} & -\frac{kab}{256} & -2k_1ab^2 \\
-\frac{ka}{64} & \frac{kab}{256} & -\frac{ka^2}{256} & -2k_1a^2b \\
-8k_1ab & 2k_1ab^2 & -2k_1a^2b & -k_2a^2b^2
\end{bmatrix}
\end{align*}
\]

\[
\begin{align*}
[\mathbf{K}_{44}] &= \\
&= \begin{bmatrix}
\frac{k}{16} & -\frac{kb}{64} & \frac{ka}{64} & 8k_1ab \\
\frac{kb^2}{256} & -\frac{kab}{256} & -2k_1ab^2 \\
(symmetric) & \frac{ka^2}{256} & 2k_1a^2b & k_2a^2b^2
\end{bmatrix}
\end{align*}
\]
Appendix B

\[
k = \frac{C_{11}^2}{C_{11}} \left[ (b/a)^2 + (a/b)^2 + 2C_{11}^2(C_{31} - 2)^2 \right]
\]

\[
k_1 = \frac{k}{2048} - C_{o}C_{11}^2 \\
k_2 = \frac{k}{4096} - C_{o}C_{11}^2 \\
C_{o} = \frac{1}{(1.58815)^2} \\
\alpha_1 = 0.98250222 \\
C_{11} = \alpha_1/(\beta_1L) \\
\beta_1L = 4.7300408
\]

\[
C_{31} = \alpha_1\beta_1L
\]

The coupling stiffness matrix, \( \{K_{ci}\} \), has the form

\[
\{K_{ci}\} = \begin{bmatrix}
K_{c1} \\
K_{c2} \\
K_{c3} \\
K_{c4}
\end{bmatrix}
\]

where

\[
\{K_{c1}\} = \begin{bmatrix}
-k/4 \\
-kb/16 \\
ka/16 \\
-32k_{1}ab
\end{bmatrix} ; \quad \{K_{c2}\} = \begin{bmatrix}
-k/4 \\
-kb/16 \\
-ka/16 \\
32k_{1}ab
\end{bmatrix}
\]

\[
\{K_{c3}\} = \begin{bmatrix}
-k/4 \\
kb/16 \\
ka/16 \\
32k_{1}ab
\end{bmatrix} ; \quad \{K_{c4}\} = \begin{bmatrix}
-k/4 \\
kb/16 \\
-ka/16 \\
-32k_{1}ab
\end{bmatrix}
\]

From equation (27), the consistent mass matrix has the form

\[
\begin{bmatrix}
\overline{p}_i \\
\overline{p}_o
\end{bmatrix} = \rho^{hab} \begin{bmatrix}
[M_{i,i}] + [\overline{M}_{i,j}] \quad [M_{ci}] \\
[M_{ci}]^T \quad [C_{o}]^2
\end{bmatrix} \begin{bmatrix}
\ddot{d} \\
\ddot{w}_o
\end{bmatrix}
\]

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The matrix \([\bar{M}_{ij}]\) has the form

\[
[\bar{M}_{ij}] = \begin{bmatrix}
\bar{M}_{11} & \bar{M}_{12} & \bar{M}_{13} & \bar{M}_{14} \\
\bar{M}_{21} & \bar{M}_{22} & \bar{M}_{23} & \bar{M}_{24} \\
\bar{M}_{31} & \bar{M}_{32} & \bar{M}_{33} & \bar{M}_{34} \\
\bar{M}_{41} & \bar{M}_{42} & \bar{M}_{43} & \bar{M}_{44}
\end{bmatrix}
\]

where

\[
[\bar{M}_{11}] = \begin{bmatrix}
r_1 & r_2 b & -r_2 a & r_4 a b \\
r_2 b^2 & -r_3 a b & r_5 a b^2 \\
r_3 a^2 & r_5 a^2 b & -r_6 a^2 b^2 \\
\end{bmatrix}
\]

(symmetric)

\[
[\bar{M}_{12}] = \begin{bmatrix}
r_1 & r_2 b & r_2 a & -r_4 a b \\
r_2 b & r_3 a^2 & r_5 a^2 b & -r_6 a^2 b^2 \\
r_3 a^2 b & -r_5 a^2 b & r_6 a^2 b^2 \\
\end{bmatrix}
\]

\[
[\bar{M}_{13}] = \begin{bmatrix}
r_1 & -r_2 b & -r_2 a & -r_4 a b \\
r_2 b & -r_3 a^2 & -r_5 a^2 b & r_6 a^2 b^2 \\
r_3 a^2 b & r_5 a^2 b & r_6 a^2 b^2 \\
\end{bmatrix}
\]
\[
\begin{align*}
\tilde{\mathbf{M}}_{14} &= 
\begin{bmatrix}
 r_1 & -r_2b & r_2a & r_4ab \\
r_2b & -r_3b^2 & r_3ab & r_5ab^2 \\
-r_2a & r_3ab & -r_3a^2 & -r_5a^2b \\
r_4ab & -r_5ab^2 & r_5a^2b & r_6a^2b^2 \\
\end{bmatrix} \\
\tilde{\mathbf{M}}_{22} &= 
\begin{bmatrix}
 r_1 & r_2b & r_2a & -r_4ab \\
r_2b & r_3b^2 & r_3ab & -r_5ab^2 \\
-r_2a & r_3ab & -r_3a^2 & -r_5a^2b \\
0 & (symmetric) & r_3a^2 & -r_5a^2b \\
\end{bmatrix} \\
\tilde{\mathbf{M}}_{23} &= 
\begin{bmatrix}
 r_1 & -r_2b & -r_2a & -r_4ab \\
r_2b & -r_3b^2 & -r_3ab & -r_5ab^2 \\
r_2a & -r_3ab & -r_3a^2 & -r_5a^2b \\
-r_4ab & r_5ab^2 & r_5a^2b & r_6a^2b^2 \\
\end{bmatrix} \\
\tilde{\mathbf{M}}_{24} &= 
\begin{bmatrix}
 r_1 & -r_2b & r_2a & r_4ab \\
r_2b & -r_3b^2 & r_3ab & r_5ab^2 \\
r_2a & -r_3ab & r_3a^2 & r_5a^2b \\
-r_4ab & r_5ab^2 & -r_5a^2b & -r_6a^2b^2 \\
\end{bmatrix} \\
\tilde{\mathbf{M}}_{33} &= 
\begin{bmatrix}
 r_1 & -r_2b & -r_2a & -r_4ab \\
r_3b^2 & r_3ab & r_5ab^2 \\
r_2a & r_3a^2 & r_5a^2b \\
0 & (symmetric) & r_3a^2 & r_5a^2b \\
\end{bmatrix} \\
\end{align*}
\]
The coupling matrix, \( \{ M_{ci} \} \), has the form

\[
\{ M_{ci} \} = \begin{pmatrix}
  M_{c1} \\
  M_{c2} \\
  M_{c3} \\
  M_{c4}
\end{pmatrix}
\]

where

\[
\begin{align*}
[r_1 & -r_2 b & r_2 a & r_4 a b \\
-r_2 b & r_3 b^2 & -r_3 a b & -r_5 a b^2 \\
-r_2 a & r_3 a b & -r_3 a^2 & -r_5 a^2 b \\
-r_4 a b & r_5 a b^2 & -r_5 a^2 b & -r_6 a^2 b^2
\end{align*}
\]

\[
[r_1 & -r_2 b & r_2 a & r_4 a b \\
 r_3 b^2 & -r_3 a b & -r_5 a b^2 \\
 r_3 a^2 & r_5 a^2 b & r_6 a^2 b^2
\]

\[
\begin{align*}
V_V & = \frac{C_0}{\left( C_0/16 - 2C_{11}^2 \right)} \\
V_V & = \frac{C_0}{\left( C_0/64 - C_{11}(C_{21} + C_{11}/4) \right)} \\
V_V & = \frac{C_0}{\left( C_0/128 - C_{11}C_{21} \right)/2} \\
V_V & = \frac{C_0}{\left( C_0/256 - C_{21}^2 - C_{11}/16 \right)} \\
V_V & = \frac{C_0}{\left( C_0/256 - C_{21}^2 - C_{21}C_{11}/4 \right)/4} \\
V_V & = \frac{C_0}{\left( C_0/512 - C_{21}^2 \right)/8} \\
C_{21} & = C_{11}/C_{31}
\end{align*}
\]
\[
\{M_{c1}\} = \begin{bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix} \quad \{M_{c2}\} = \begin{bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix}
\]

\[
\{M_{c3}\} = \begin{bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix} \quad \{M_{c4}\} = \begin{bmatrix}
-r_7 \\
r_8^b \\
r_8^a \\
r_9^{ab}
\end{bmatrix}
\]

\[r_7 = 2C_o(C_o/16 - C_{11}^2)\]
\[r_8 = 2C_o(C_o/64 - C_{11}C_{21})\]
\[r_9 = 2C_o(C_o/256 - C_{21}^2)\]
APPENDIX C

COMPUTER PROGRAM DESCRIPTIONS, FLOW CHARTS,
AND CARD IMAGE LISTINGS

This appendix contains the computer program descriptions, flow charts, and listings for the one-dimensional panel and the two-dimensional panel modal analyses. The program descriptions list the purpose of the program or subprogram, the subprograms required, definition of primary variables, restrictions, accuracy (when applicable), and compiled size (octal) of the program for the NASA Langley CDC 6600 computer.
Appendix C

ONE-DIMENSIONAL PANEL ANALYSIS: MAIN PROGRAM AND SUBPROGRAMS IN ORDER OF APPEARANCE
PROGRAM BMPROP (MAIN)
(See Figure 1 for Flow Chart)

PURPOSE: Main program for computing natural frequencies, normal mode shapes, modal shear distribution, and modal bending moment distribution along the centerline of a one-dimensional panel array undergoing cylindrical bending (beam analogy). A fundamental clamped-clamped mode across the panel width is assumed. Elastic supports are introduced as lumped spring-mass constants and lumped masses are introduced as a support with zero stiffness. Clamped or elastic supports can be introduced at either end of the structure.

SUBPROGRAMS REQUIRED: ELEM, ASSY, LOC, NONDIM, ORDER, DELETE, FREQ, NROOT, EIGEN, SSBM

INPUT DATA: See Appendix D for description - NCASE, NDATA, NBAY, NSUP, IOUT, IBL, IBR, NINT, BW, PR, NEL(I), EI(I), WB(I), BL(I), NCP(I), SL(I), SC(I), SR(I), RL(I), RC(I), PR(I)

VARIABLES: NDEL(N) - Constraint vector for an N degree-of-freedom system. If NDEL(J) = 0, the Jth coordinate is unconstrained; if NDEL(J) = 1, the Jth coordinate is constrained (deleted from the equations of motion).

R(N) - Consistent mass matrix - dimension N(N + 1)/2 for N degree-of-freedom system.

S(N) - Stiffness matrix - dimension N(N + 1)/2 for N degree-of-freedom system.

S1(4), S2(4), S3(4) - Dummy arrays for assembling the element stiffness in matrix S(N) and the element mass in matrix R(N).

DUM3(2293) - Dummy array for eigenvalue calculation.

RESTRICTIONS: For the declared size of the arrays 2(ΣNEL(I) + 1) ≤ 38, NBAY ≤ 5.

SIZE: 005152
PROGRAM BMPPROP (INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT)
DIMENSION BL(5), NEL(5), NDEL(38), R(741), S(741)
DIMENSION SL(5), SC(5), SR(5), RL(6), RC(6), RR(6)
DIMENSION SI(4), S2(4), S3(4), NC(6)
DIMENSION EI(5), NU(5), SLMT(5), DUM3(220)
COMMON R, S
COMMON EI, WB, BLMT, BW, PR
COMMON TL, SL, SC, SR, RL, RC, RR, NEL, NC
COMMON BL, S1, S2, S3, NDEL, DUM3
IN=5
IO=6
ICASE=1
READ(IN, 120) NCASE
100 READ(IN, 120) NDATA, NBAY, NSUP, IOUT, IBL, IBR, NINT
READ(IN, 125) BW, PR
READ(IN, 130) (NEL(I), EI(I), WB(I), BL(I), I=1, NBAY)
IF(NSUP) 110 110 105
105 DO 110 I=1, NSUP
READ(IN, 130) NC(1), SL(I), SC(I), SR(I)
READ(IN, 140) RL(I), RC(I), RR(I)
110 CONTINUE
WRITE(IO, 145)
WRITE(IO, 150) NDATA
WRITE(IO, 155) NBAY, NSUP
WRITE(IO, 160) BW, PR
WRITE(IO, 165)
WRITE(IO, 170)
DO 175 I=1, NBAY
WRITE(IO, 180) I, NEL(I), EI(I), WB(I), BL(I)
175 CONTINUE
DO 181 I=1, NSUP
WRITE(IO, 182) I, NC(1)
WRITE(IO, 183) SL(I), SC(I), SR(I)
WRITE(IO, 184) RL(I), RC(I), RR(I)
181 CONTINUE
TL=0.0
Tk=0.0
TM=0.0
NCT=0
DO 200 I=1, NBAY
BLMT(I)=BL(I)/FLOAT(NEL(I))
TL=TL+BL(I)
NCT=NCT+NEL(I)
200 CONTINUE
NGP=NCT+1
NC0=2*NGP
NUP=NC0*(NC0+1)/2
DO 240 IOP=1, 2
DO 210 I=1, NUP
R(J)=0.0
210 CONTINUE
NUT=0
DO 220 J=1, NBAY
CALL ELEM(J, IOP, S1, S2, S3)
NU=NEL(J)
NUT=NUT+NU
DO 220 I=1, NU
ICN=2*(I+NUT-NU)-1

PROGRAM BMPPROP: CARD IMAGE LISTING 1/3
ICS=ICN+2
CALL ASSY(NCO,ICN,ICS,R,S1,S2,S3,2)

220 CONTINUE
IF(10P-1) 230,230,240

230 DO 235 I=1,NUP
S(I)=R(I)
235 CONTINUE

240 CONTINUE

IF(NSUP) 250,250,245

245 DO 250 I=1,NSUP

J=NCPT(I)
K=J+1
JJ=J+(J*J-J)/2
JK=J+(K*K-K)/2
KK=K+(K*K-K)/2
S(JJ)=S(JJ)+SL(I)
S(JK)=S(JK)+SR(I)
S(KK)=S(KK)+SR(I)
R(JJ)=R(JJ)+RL(I)/386.0
R(JK)=R(JK)+RC(I)/386.0
R(KK)=R(KK)+RR(I)/386.0

250 CONTINUE

C NONDIMENSIONALIZE STIFFNESS MATRIX

DO 255 I=2,NCO+2
II=I*(I+1)/2
TK=TK+S(I)
255 CONTINUE

TL=TL/FLOAT(NCT)
TK=TK/FLOAT(NCT)
TM=TM/FLOAT(NCT)

CALL NONDIM(S,NCO,TL,TK)
CALL NONDIM(R,NCO,TL,TM)

C APPLY CONSTRAINTS

NDL=0
DO 261 J=1,NCO
NDL(J)=0
261 CONTINUE

IF(1UL) 264,264,262

262 ND(1)=1
ND(2)=1
DO 263 I=1,NSUP
NC(I)=NC(I)-2
263 CONTINUE

IF(1UL) 270,270,265

IC=NCO-1
ND(1C)=1
ND(NCO)=1
CALL ORDER(S,NDL,NGP,NDL)
CALL ORDER(R,NDL,NGP,NDL)

270 NCO=NCO-NDL
NUP=NCO*(NCO+1)/2

WRITE(10,280)
WRITE(10,285) NCO,TK,TL
WRITE(10,290) (S(I),I=1,NUP)
WRITE(10,300)
WRITE(10,305) NCO,TM,TL
WRITE(10,290) (R(I),I=1,NUP)

PROGRAM BMPROP: CARD IMAGE LISTING 2/3
Appendix C

C COMPUTE EIGENVALUES AND EIGENVECTORS
315 WRITE(10,320) TL,TK,TM
CALL FREQ(SX,TL,TK,TM,NDATA,NCO)
IF(IOUT-I) 100,100,260
260 CALL SSBM(NCO,NBAY,NSUP,I BL,NINT,NDATA)
ICASE=ICASE+1
IF(NCASE-ICASE) 205,100,100
205 CONTINUE
120 FORMAT(I9,6I3)
125 FORMAT(3X,2E12.5)
130 FORMAT(I3,3E12.5)
140 FORMAT(3X,3E12.5)
145 FORMAT(IHI,7X,47HFREE VIBRATION OF A ONE DIMENSIONAL PANEL ARRAY)
150 FORMAT(/,25X,9HDATA CASE , I4)
155 FORMAT(/,4X,15HNUMBER OF BAYS = , I3, 19X, 19HNUMBER OF SUPPORTS= , I3)
160 FORMAT(/,4X,12HPANEL WIDTH= , E12.5, 7X, 16HPoisson'S RATIO= , E12.5)
165 FORMAT(/,5X,3HBAY, 5X, 9HNUMBER OF = , 3X, 7HBENDING , 6X, 10HWEIGHT PER,
18X, 3HBAY)
170 FORMAT(/,4X,6HNUMBER, 3X, 8HELEMENTS, 4X, 8HRIGIDITY, 5X,
19HUNIT AREA, 6X, 6HLENGTH/)
180 FORMAT(/,5X,13, 7X, 13, 5X, E12.5, 1X, E12.5, 3X, E12.5)
182 FORMAT(/,4X,11HSUPPORT NO., I3, 25X, 17HINPUT COORDINATE =, I3)
183 FORMAT(/,4X,4HKZZ= , E12.5, 2X, 8HIZTHETA= , E12.5)
184 FORMAT(/,4X,4HIZZ= , E12.5, 2X, 8HIIZTHETA= , E12.5)
280 FORMAT(/,5X,4HNCO= , I4, 2X, 3HTK= , E12.5, 2X, 3HTL= , E12.5)
290 FORMAT(8E12.5)
300 FORMAT(1H1, 4X, 11HMMASS MATRIX)
305 FORMAT(/,5X,4HNCO= , I4, 2X, 3HTM= , E12.5, 2X, 3HTL= , E12.5)
310 FORMAT(6E11.4)
320 FORMAT(3E12.5)
END
SUBROUTINE ELEM (I, IOP, S1, S2, S3)

PURPOSE: To compute the stiffness (IOP = 1) and the consistent mass matrix (IOP = 2) for a panel element in the $i^{th}$ bay of the structure. The partitioned stiffness or mass matrix is assigned to the arrays S1, S2, S3 where S1 is the direct stiffness or mass term at end 1 of the element, S2 is the coupling term between ends 1 and 2, and S3 is the direct term at end 2 of the element.

SUBPROGRAMS REQUIRED: None

VARIABLES:

I - Panel Bay Number
IOP - Logic number: IOP = 1, stiffness matrix for element is calculated; IOP = 2, consistent mass matrix is calculated.
S1, S2, S3 - See 'Purpose' above
EL(I) - Bending rigidity of element
WB(I) - Weight percent length of element
BL(I) - Length of element

RESTRICTIONS: None

SIZE: 000152

REFERENCE: Reference 1, pp. 9 – 11.
Appendix C

BEGIN

A = LENGTH OF ELEMENT IN ITH BAY OF PANEL

YES

IOP > 1

D = MASS COEFFICIENT OF ITH BAY OF PANEL
STATEMENT NO. 15

NO

D = STIFFNESS COEFFICIENT OF ITH BAY OF PANEL
STATEMENT NO. 10

COMPUTE THE PARTITIONED CONSISTENT MASS MATRIX FOR THE ELEMENT

RETURN

COMPUTE THE PARTITIONED STIFFNESS MATRIX FOR THE ELEMENT

FLOW CHART: SUBPROGRAM ELEM (I, IOP, S1, S2, S3)
SUBROUTINE ELEM (I, IOP, S1, S2, S3)
DIMENSION S1(1), S2(1), S3(1), DUM1(1482)
DIMENSION EI(5), WB(5), BL(5)
COMMON DUM1, EI, WB, BL, BW, PR
A = BL(1)
AS = A*A
IF (IOP-1) 10, 10, 15
10 D = EI(I)/(A*AS)
S1(1) = 12.0*D
S2(2) = 6.0*D*A
S1(3) = 4.0*D*AS
S2(1) = -12.0*D
S2(2) = -6.0*D*A
S2(3) = 6.0*D*A
S2(4) = 2.0*D*AS
S3(1) = 12.0*D
S3(2) = -6.0*D*A
S3(3) = 4.0*D*AS
RETURN
15 D = WB(1)*A/386.0
S1(1) = 13.0*D/35.0
S1(2) = 11.0*D*A/210.0
S1(3) = 0*AS/105.0
S2(1) = 9.0*D/70.0
S2(2) = 13.0*D*A/420.0
S2(3) = -13.0*D*A/420.0
S2(4) = 0*AS/140.0
S3(1) = 13.0*D/35.0
S3(2) = -11.0*D*A/210.0
S3(3) = 0*AS/105.0
RETURN
END

SUBPROGRAM ELEM: CARD IMAGE LISTING
SUBROUTINE ASSY (N, ICN, ICS, A, E1, E2, E3, NLM)

PURPOSE: To assemble (add) the partitioned element stiffness or mass matrices (E1, E2, E3) in the appropriate location of the global stiffness or mass matrix A.

SUBPROGRAMS REQUIRED: LOC

VARIABLES:
N - Size of matrix A (See Subroutine LOC).
ICN - Initial coordinate for diagonal location of E1 in A.
ICS - Initial coordinate for column location of E2 in A for row ICN.
NLM - The number of coordinates at each grid point for the element described by E1, E2, and E3. For the one-dimensional analysis NLM = 2.

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 0001438
Appendix C

BEGIN

SET ROW NUMBER (K) AND COLUMN NUMBER (L) FOR PARTITIONED ELEMENT MATRICES

STEP 4.1

COMPUTE SUBSCRIPTS FOR SYMMETRIC ELEMENT MATRICES E1 AND E3 [(K, L) → KLS] AND FOR GENERAL ELEMENT MATRIX E2 [(K, L) → KLG]

SUBROUTINE LOC

STEP 4.2

COMPUTE INITIAL ROW NUMBER (INK) AND COLUMN NUMBER (INL) TO LOCATE ELEMENT MATRIX E1(KLS) IN THE ASSEMBLED MATRIX A

STEP 4.3

COMPUTE SUBSCRIPT FOR THE LOCATION (INK, INL) → NKL IN THE ASSEMBLED MATRIX A

SUBROUTINE LOC

STEP 4.4

COMPUTE SECONDARY ROW NUMBER (ISK) AND COLUMN NUMBER (ISL) TO LOCATE ELEMENT MATRIX E3(KLS) IN THE ASSEMBLED MATRIX A

STEP 4.5

COMPUTE SUBSCRIPT FOR THE LOCATION (ISK, ISL) → IKL IN THE ASSEMBLED MATRIX A

SUBROUTINE LOC

STEP 4.6

A

FLOW CHART: SUBPROGRAM ASSY (N, ICN, ICS, A, E1, E2, E3, NLM)
Appendix C

ADD (ASSEMBLE) ELEMENT MATRICES $E_1(KLS)$ & $E_3(KLS)$ TO $A(NKL)$ AND $A(IKL)$, RESPECTIVELY

ADD ELEMENT MATRIX $E_2(KLG)$ TO ASSEMBLED MATRIX $A(IKS)$

IS ELEMENT ROW AND COLUMN COUNT FINISHED?

RETURN

STEP 4.8

STEP 4.9

FLOW CHART: SUBPROGRAM ASSY ($N, ICN, ICS, A, E_1, E_2, E_3, NLM$)
SUBROUTINE ASSY(N, ICN, ICS, A, E1, E2, E3, NLM)
DIMENSION A(1), E1(1), E2(1), E3(1)

DO 20 K=1, NLM
    DO 20 L=1, NLM
        CALL LOC(K, L, KLS, NLM, 1)
        CALL LOC(K, L, KLG, NLM, 0)
        INK = ICN + K - 1
        INL = ICN + L - 1
        CALL LOC(INK, INL, NKL, N, 1)
        ISK = ICS + K - 1
        ISL = ICS + L - 1
        CALL LOC(ISK, ISL, IKS, N, 1)
        IF (K - L) GT 10 CONTINUE
10    A(NKL) = A(NKL) + E1(KLS)
    A(IKL) = A(IKL) + E3(KLS)
15    A(IKS) = A(IKS) + E2(KLG)
    CONTINUE
20 CONTINUE
RETURN
END

SUBPROGRAM ASSY: CARD IMAGE LISTING

73
SUBROUTINE LOC (I, J, IR, N, MS)

PURPOSE: To calculate a single subscript, IR, for a double subscripted square array, A, of size NXN for a row-column location (I, J). MS is a logic number for calculating the subscript IR.

MS = 0, General Storage, array is assumed to be dimensioned as 
A(R)  R = NXN

MS = 1, Symmetric Storage, array is assumed to be dimensioned as 
A(R)  R = N (N + 1)/2

MS = 2, Diagonal Storage, array is assumed to be dimensioned as 
A(R)  R = N

SUBPROGRAMS REQUIRED: None

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000057

REFERENCES: Reference 3
BEGIN

SELECT SUBSCRIPT MODE
MS = 0, GENERAL MODE
MS = 1, SYMMETRIC MODE
MS = 2, DIAGONAL MODE

IR = N*(J-1) + 1

MS = 1
IF I ≥ J
THEN YES
RETURN

MS = 2
IR = J + (I*1 - 1)/2
RETURN

I = J
IF I = J
THEN YES
IR = 1
RETURN

IF MS = 0
THEN
IR = N*(J-1) + 1
RETURN

FLOW CHART: SUBPROGRAM LOC(I, J, IR, N, MS)
SUBROUTINE LOC(I,J,IR,N,MS)
C THIS SUBROUTINE COMPRESSES A TWO DIMENSIONAL
C ARRAY INTO A ONE DIMENSIONAL ARRAY
C MS=0 IS FOR GENERAL STORAGE
C MS=1 IS FOR SYMMETRIC STORAGE
C MS=2 IS FOR DIAGONAL STORAGE
C IX=I
JX=J
IF(MS=1) 10,20,30
10 IRX=N*(JX-1)+IX
GO TO 36
20 IF(IX-JX) 22,24,24
22 IRX=IX+(JX*JX-JX)/2
GO TO 36
24 IRX=JX+(IX*IX-IX)/2
GO TO 36
30 IRX=0
IF(IX-JX) 36,32,36
32 IRX=IX
36 IR=IRX
RETURN
END
SUBROUTINE NONDIM (A,N,TL,TIC)

PURPOSE: To nondimensionalize the free-free stiffness and mass matrix of the structure.

SUBPROGRAMS REQUIRED: LOC

VARIABLES: 
A(N) – Stiffness on mass matrix to be nondimensionalized
N – Size of array A (MS = 1 in LOC)
TL – Arbitrary length parameter (taken as the average element length of the structural idealization)
TK – Arbitrary stiffness parameter (taken as the average rotational stiffness of the structural idealization)

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000133
BEGIN

SET INDEX FOR ROTATION COORDINATE (I) AT GRID POINT

COMPUTE INDICES FOR TRANSLATION COORDINATE (I1) AT GRID POINT AND TRANSLATION AND ROTATION COORDINATES (I2 AND I3, RESPECTIVELY) AT NEXT GRID POINT

COMPUTE SUBSCRIPTS FOR TRANSLATION AND COUPLING COORDINATES (I11 AND I11) FOR GRID POINT

MULTIPLY ELEMENTS OF MATRIX A BY THE LENGTH PARAMETER, TL

A(I11) = TL*TL*A(I11)
A(I11) = TL*A(I11)

YES

I ≥ N

NO

COMPUTE INDICES FOR TRANSLATION AND COUPLING TERMS (I12, I13, I12) FOR COUPLING MATRIX BETWEEN GRID POINTS

MULTIPLY ELEMENTS OF MATRIX A BY THE LENGTH PARAMETER, TL

A(I12) = TL*TL*A(I12)
A(I13) = TL*A(I13)
A(I12) = TL*A(I12)

YES

I ≥ N

NO

GOTO STEP 6.1

DIVIDE ALL ELEMENTS IN MATRIX A BY THE PARAMETER TK

RETURN

FLOW CHART: SUBPROGRAM NONDIM (A, N, TL, TK)
SUBROUTINE NONDIM(A,N,TL,TK)

DIMENSION A(N)

DO 3 I=2*N+2
   I1=I+1
   I2=I+1
   I3=I+2
   I11=I1+(I1*I1-I1)/2
   I11=I11+(I11*I11-I11)/2
   A(I11)=TL*TL*A(I11)
   A(I11)=TL*A(I11)
   I2=I2+1
   I3=I3+1
   I13=I3+(I3*I3-I3)/2
   I12=I2+(I2*I2-I2)/2
   A(I12)=TL*TL*A(I12)
   A(I12)=TL*A(I12)
   CONTINUE

DO 4 I=1,N
   DO 4 J=I,N
      CALL LOC(I,J,1,N,A(IJ))
      A(IJ)=A(IJ)/TK

CONTINUE
RETURN

END

SUBPROGRAM NONDIM: CARD IMAGE LISTING
SUBROUTINE ORDER (A, NDEL, NGP, NDL)

PURPOSE: To remove (set to zero) specified (constrained) coordinates in array A, reorder the array A, and calculate the new size of array A.

SUBPROGRAMS REQUIRED: DELETE, LOC

VARIABLES:

A(I) - Stiffness or mass matrix of structural idealization
   (symmetric storage mode: LOC)

NDEL(I) - Array of logic numbers: See BMPROP

NGP - Number of grid points of the structure

NDL - Number of coordinates removed by this subprogram

NC(38) - Array of coordinate numbers for which NDEL(I) = 1

RESTRICTIONS: NGP is assumed to be equal to or less than 19.

NC(I) must be dimensioned the same as NDEL(I) in program BMPROP

ACCURACY: Not Applicable

SIZE: 000244
Appendix C

BEGIN

INITIALIZE DATA

SELECT GRID POINT, IC

COMPUTE SUBSCRIPTS FOR COORDINATES AT GRID POINT IC
TRANSLATION SUBSCRIPT, J
ROTATION SUBSCRIPT, II

STEP 7.1
STEP 7.2
STEP 7.3

STEP 7.4
STEP 7.5

STEP 7.6
STEP 7.7

STEP 7.8
STEP 7.9

FLOW CHART: SUBPROGRAM ORDER (A, NDEL, NGP, NDL)
Appendix C

SELECT COORDINATE, M, TO BE DELETED

COMPUTE CURRENT SIZE, N, OF MATRIX A

SET TO ZERO ALL ELEMENTS (ROW AND COLUMN) FOR COORDINATE M IN SYMMETRIC MATRIX, A

SUBROUTINE DELETE

BEGINNING WITH COORDINATE M REPLACE ROW AND COLUMN LOCATIONS OF M BY COORDINATE (M+1), (M+1) BY (M+2), ETC., UNTIL FINAL COORDINATE IS ENCOUNTERED

REORDER COORDINATES, NC(I), TO BE DELETED

HAVE ALL SPECIFIED COORDINATES BEEN DELETED?

YES

NO

STEP 7.10

STEP 7.11

STEP 7.12

STEP 7.13

STEP 7.14

STEP 7.15

STEP 7.16

RETURN

FLOW CHART: SUBPROGRAM ORDER (A, NDEL, NGP, NDL)
SUBROUTINE DELETE (A, N, J)

PURPOSE: To delete (set to zero) all elements in the $J^{th}$ row column of array A.

SUBPROGRAMS REQUIRED: LOC

VARIABLES: A(N) - Single subscripted array (symmetric storage mode: LOC)
            N   - Size of array A
            J   - Row-column number of elements of A to be set to zero

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000034

Appendix C
SUBROUTINE ORDER(A,N,DEL,NGP,NOL)
DIMENSION A(I),NDEL(I),NC(38)
NDL=0
NC0=2*NGP
DO 1 I=1,NC0
NC(I)=0
1 CONTINUE
DO 5 IC=1,NGP
I=2*IC-1
J=2*IC
IF(NDEL(I)) 3,3,2
2 NDL=NDL+1
NC(NDL)=I
3 IF(NDEL(J)) 5,5,4
4 NDL=NDL+1
NC(NDL)=J
5 CONTINUE
DO 11 K=1,NOL
M=NC(K)
ML=NC0-K
N=ML+1
CALL DELETE(A,N,M)
DO 9 I=M,ML
I=I+1
DO 9 J=1,N
CALL LOC(I,J,1,J,N,1)
IF(I-J) 7,6,7
6 J=J+1
CALL LOC(I,I,J,1,J1,N,1)
GO TO 8
7 CALL LOC(I,I,J,1,J1,N,1)
8 A(IJ)=A(IJ1)
9 CONTINUE
DO 11 I=1,NDL
IF(NC(I)=M) 11,11,10
10 NC(I)=NC(I)-1
11 CONTINUE
M=NC0-NDL+1
DO 12 K=M,NC0
CALL DELETE(A,NC0,K)
12 CONTINUE
RETURN
END

SUBROUTINE DELETE(A,N,J)
DIMENSION A(I)
DO 1 K=1,N
CALL LOC(K,J,KJ,N,1)
A(KJ)=0.0
1 CONTINUE
RETURN
END

SUBPROGRAMS ORDER AND DELETE: CARD IMAGE LISTING
SUBROUTINE FREQ (SS, RR, TL, TK, TM, NCASE, N)

PURPOSE: To convert the stiffness, SS, and mass, RR, matrices (symmetric storage mode: LOC) to the stiffness, S, and mass, R, matrices (general storage mode: LOC); call for eigenvalue calculations, and write the eigenvalues (frequency) and eigenvectors.

SUBPROGRAMS REQUIRED: LOC, NROOT (NROOT requires EIGEN)

VARIABLES: SS(NUP) - Dimensionless stiffness matrix
RR(NUP) - Dimensionless mass matrix
TL - Length parameter used in nondimensionalization
TK - Stiffness parameter used in nondimensionalization
TM - Mass parameter used in nondimensionalization
NCASE - Data case identification number
N - Number of coordinates

RESTRICTIONS: For the declared size of the arrays, N \leq 19

ACCURACY: See NROOT and EIGEN

SIZE: 000256 \_B
Appendix C

BEGIN

WRITE DATA SET IDENTIFICATION NUMBER

FILL COMPLETE STIFFNESS, S(I), AND MASS, R(I), MATRICES (STORAGE MODE 0) WITH SYMMETRIC STIFFNESS, SS(II) AND MASS, RR(I), MATRICES (STORAGE MODE 1)

COMPUTE EIGENVALUES, EVL(I), AND EIGENVECTORS, EVC(I), SUBROUTINE NR00T

IN THE ORDER OF DECREASING MAGNITUDE, WRITE THE EIGENVALUE (UNITS - Hz) AND THE EIGENVECTOR FOR EACH COORDINATE OF THE SYSTEM

RETURN

FLOW CHART: SUBPROGRAM FREQ (SS, RR, TL, TK, TM, NCASE, N)
SUBROUTINE FREQ(SS, RR, TL, TK, TM, NCASE, N)
DIMENSION SS(1), RR(1), EVL(3N), EVC(NCASE)
DIMENSION S(156), R(156), DUM1(342), DUM2(17)
COMMON EVL, EVC, DUM1, DUM2, S, R
I0=6
NUP=N*(N+1)/2
WRITE (IO, 120)
WRITE (IO, 125) NCASE
DO 205 I=1,N
DO 205 J=1,N
CALL LOC(I, J, IJ, N, 0)
CALL LOC(I, J, IJS, N+1)
S(IJ)=SS(IJS)
R(IJ)=RR(IJS)
CONTINUE
CALL NROOT(N, S, R, EVL, EVC)
IF(EVL(I)) 210, 215, 215
210 EVL(I)=ABS(EVL(I))
215 EVL(I)=0.159155*SQRT(TK*EVL(I)/TM)
WRITE (IO, 225) EVL(I)
WRITE (IO, 230)
IY=N*(I-1)+1
IY=N+I
WRITE (IO, 235) (EVC(J), J=IY, 1Y)
CONTINUE
RETURN
FORMAT(1H1, 27X, 24HFREQUENCY OF A ONE-DIMENSIONAL PANEL ARRAY)
FORMAT(4X, 9HDATA CASE, I4, /)
FORMAT(5X, 10HFREQUENCY=, El2.5, 1X, 3HZ, /)
FORMAT(5X, 10HMODE SHAPE, /)
FORMAT(5X, 8E12.5)
FORMAT(5E15.8)
END
SUBROUTINE NROOT (M, A, B, XL, X)

PURPOSE: To compute the eigenvalues and eigenvectors of a real symmetric matrix of the form B-inverse times A.

SUBPROGRAMS REQUIRED: EIGEN

VARIABLES:

- **M**: Order of square matrices A, B, and X
- **A**: Input matrix, MXM, (stiffness matrix)
- **B**: Input matrix, MXM, (mass matrix)
- **XL**: Output vector of length M containing eigenvalues of B-inverse times A
- **X**: Output matrix, MXM, containing eigenvectors column wise

RESTRICTIONS: See EIGEN

ACCURACY: See EIGEN

SIZE: 0003128

REFERENCES: References 3 and 4
SUBROUTINE NKOOT (M, A, B, XL, X)
DIMENSION A(1), B(1), XL(1), X(1)

C COMPUTE EIGENVALUES AND EIGENVECTORS OF B
K=1
DO 100 J=2, M
L=M*(J-1)
DO 100 I=1, J
L=L+1
100 B(K)=B(L)

C THE MATRIX B IS A REAL SYMMETRIC MATRIX
MV=0
CALL EIGEN(B, X, M, MV)

C FORM RECIPROCAL OF SQUARE ROOT OF EIGENVALUES. THE RESULTS ARE PREMULTIPLIED BY THE ASSOCIATED EIGENVECTORS.
L=0
DO 110 J=1, M
L=L+J
110 XL(J)=1.0/SQRT(ABS(B(L)))

C THE MATRIX A IS A REAL SYMMETRIC MATRIX
MV=0
CALL EIGEN(A, X, M, MV)

C FORM (B**(-1/2))P*R*(B**(-1/2))
DO 120 I=1, M
N2=0
DO 120 J=1, M
N1=M*(I-1)
L=M*(J-1)+I
X(L)=0.0
DO 120 K=1, M
120 X(L)=X(L)+B(N1)*A(N2)

C COMPUTE EIGENVALUES AND EIGENVECTORS OF MATRIX A
C
L=0
DO 140 I=1, M
L=L+1
140 XL(I)=A(L)

C COMPUTE NORMALIZED EIGENVECTORS
DO 150 I=1, M
N2=0
DO 150 J=1, M
N1=I-M

SUBPROGRAM NROOT: CARD IMAGE LISTING 1/2
\[ L = M \times (J-1) + 1 \]

\[ A(L) = 0.0 \]

\[ N_1 = N_1 + M \]

\[ N_2 = N_2 + 1 \]

\[ A(L) = A(L) + B(N1) \times X(N2) \]

\[ L = 0 \]

\[ K = 0 \]

\[ N_2 = N_2 + 1 \]

\[ U_0 150 \quad K = 1 \times M \]

\[ N_1 = N_1 + M \]

\[ U_0 150 \quad K = 1 \times M \]

\[ L = L + 1 \]

\[ 170 \quad \text{SUMV} = \text{SUMV} + A(L) \times A(L) \]

\[ 175 \quad \text{SUMV} = \text{SQRT} \left( \text{SUMV} \right) \]

\[ U_0 180 \quad I = 1 \times M \]

\[ K = K + 1 \]

\[ 180 \quad X(K) = A(K) / \text{SUMV} \]

\[ \text{RETURN} \]

\[ \text{END} \]
SUBROUTINE EIGEN (A,R,N,MV)

PURPOSE: To compute eigenvalues and eigenvectors of a real symmetric matrix by the Jacobi method.

SUBPROGRAMS REQUIRED: None

VARIABLES:  
A - Original matrix (symmetric storage mode: LOC), destroyed in computation. Resultant eigenvalues are developed in diagonal of matrix A in descending order.

R - Resultant matrix of eigenvectors (stored column wise, in same sequence as eigenvectors).

N - Order of matrices A and R

MV - Input option

0  Compute eigenvalues and eigenvectors
1  Compute eigenvalues only (R need not be dimensioned but must still appear in calling sequence)

RESTRICTIONS:  The original matrix A must be real symmetric (storage mode 1: LOC). Matrix A cannot be in the same location as matrix R.

ACCURACY:  At each step of the diagonalization a norm is calculated and the diagonalization continued with the magnitude of the off-diagonal term is sufficiently small to insure convergence.

SIZE: 000522

REFERENCES: References 3 and 4
SUBROUTINE EIGEN(A, N, MV)
DIMENSION A(1), R(1)

C GENERATE IDENTITY MATRIX
5 RANGE = 1.0E-6
10 IF(MV=1) 10, 25, 10
10 IG = -N
DO 20 J = 1, N
20 IG = IG + N
DO 20 I = 1, N
20 R(I, J) = 0.0
IF(I = J) 30, 15, 20
30 R(I, J) = 0.0
IF(I = J) 20, 15, 20
15 R(I, J) = 1.0
20 CONTINUE

C COMPUTE INITIAL AND FINAL NORMS (ANORM AND ANORMX)
25 ANORM = 0.0
DO 35 I = 1, N
35 CONTINUE
IF(I = J) 165, 165, 40
40 ANORM = ANORM + A(IA)**2
CONTINUE
IF(ANORM) 165, 165, 40
40 ANORM = 1.414*SQRT(ANORM)
ANORMX = ANORM*RANGE/FLOAT(N)

C INITIALIZE INDICATORS AND COMPUTE THRESHOLD, THR
IND = 0
THR = ANORM
45 THR = THR/FLOAT(N)
50 L = 1
55 M = L + 1
C COMPUTE SIN AND COS
50 MQ = (M*M-M)/2
50 LQ = (L*L-L)/2
LM = L + MQ
62 IF(ABS(A(LM)) - THR) 130, 65, 65
65 IND = 1
65 LL = L + LQ
65 MM = M + MQ
65 X = 0.5*(A(LL) - A(MM))
65 Y = -A(LM)**2/SORT(A(LM)**2 + X**2)
65 IF(X) 70, 75, 75
70 X = X
75 SINX = Y/SORT(2.0*(1.0 - SQRT(1.0 - Y**2))**2)
75 COSX = SQRT(1.0 - SINX**2)
78 C0S2 = COSX**2
78 SINS2 = SINX**2

C ROTATE L AND M COLUMNS
ILQ = N*(L-1)
IMQ = N*(M-1)
DO 125 I = 1, N
125 IG = (I*I-1)/2
125 IF(I-L) 80, 115, 80
80 IF(I = M) 85, 115, 90
85 IMP = IM + MQ
60 TO 95

SUBPROGRAM EIGEN: CARD IMAGE LISTING 1/2
90 IM=M+1Q  
95 IF(I-L) 100,105,105
100 IL=I+1Q  
GO TO 110
105 IL=L+1Q
110 X=A(II)*COSX-A(IM)*SINX
       A(IM)=A(II)*SINX+A(IM)*COSX
       A(II)=X
115 IF(MV-1) 120,125,120
120 ILR=ILQ+1  
       IMR=IMQ+1
       X=R(ILR)*COSX-R(IMR)*SINX
       R(IMR)=R(ILR)*SINX+R(IMR)*COSX
       R(ILR)=X
125 CONTINUE
       X=250*A(LM)*SINCS
       Y=A(LL)*COS2+A(MM)*SIN2-X
       X=X+A(LL)*COS2+A(MM)*SIN2
       A(LL)=(A(LL)-A(MM))*SINCS+A(LM)*(COS2-SIN2)
       A(MM)=Y
C TESTS FOR COMPLETION
C TEST FOR M = LAST COLUMN
130 IF(M-N) 135,140,135
135 M=M+1
GO TO 60
C TEST FOR L = SECOND FROM LAST COLUMN
140 IF(L-(N-1)) 145,150,145
145 L=L+1
GO TO 55
150 IF(IND-1) 160,155,160
155 IND=0
GO TO 50
C COMPARE THRESHOLD WITH FINAL NORM
160 IF(THR-ANRMX) 165,165,45
C SORT EIGENVALUES AND EIGENVECTORS
165 IQ=-N
   DO 185 I=1,N
      IQ=IQ+N
      LL=I+(I*I-I)/2
      JG=N*(I-2)
      DO 185 J=I,N
      JQ=JQ+N
      MM=J+(J*J-J)/2
      IF(A(LL)-A(MM)) 170,185,185
170 X=A(LL)
       A(LL)=A(MM)
       A(MM)=X
   IF(MV-1) 175,185,175
   DO 180 K=1,N
      ILR=IQ+K
      IMR=JQ+K
      X=R(ILR)
      R(ILR)=R(IMR)
180 R(IMR)=X
185 CONTINUE
RETURN
END

SUBPROGRAM EIGEN: CARD IMAGE LISTING 2/2
SUBROUTINE SSBM (NCO, NBAY, NSUP, IBL, NINT, NDATA)

PURPOSE: To compute the displacement, slope, shear, and bending moment
distribution along the centerline of the panel row for the fifteen
lower frequency modes of the structure. The displacement, slope,
shear, and bending moment distribution are calculated at each
element node point and at NINT points interior to the element.
All values are normalized to the maximum value and printed.

SUBPROGRAMS REQUIRED: ELEM

VARIABLES:
NCO    - Number of coordinates for the structural idealization
NBAY   - Number of panel bays of the structure
NSUP   - Number of elastic supports
IBL    - Logic number: IBL = 0, the left end of the structure is
        free or elastically supported; IBL = 1, the left end of the
        structure is clamped.
NINT   - Number of points interior to an element for which inter-
polated values of displacement, slope shear and bending
moment are to be calculated.
NDATA  - Four digit data case identification number

RESTRICTIONS: For the declared size of the arrays: NCO ≤ 38, NBAY ≤ 5,
              NSUP ≤ 6, NINT ≤ 5.

ACCURACY: (See NROOT and EIGEN)

SIZE: 0011148

REFERENCE: Reference 1, pp. 9 - 11.
BEGIN

STEP 10.1

COMPUTE INTERVAL SIZE, STP, AND NUMBER OF POINTS, NINT, FOR COMPUTING VALUES ALONG ELEMENT

STEP 10.2

SET MODE NUMBER, I
ONLY LOWER FREQUENCY MODES I ≤ 15 ARE COMPUTED

COMPUTE INDEX FOR EIGENVALUE
COMPUTE SUBSCRIPT LIMITS FOR EIGENVECTOR
WRITE EIGEN VALUE

COMPUTE \( \omega^2 \)

STEP 10.3

STEP 10.4

STEP 10.5

STEP 10.6

STEP 10.7

YES

THIS THE FIRST BAY? J=1

NO

STEP 10.8

IS THE FIRST BAY CLAMPED AT THE L.H. END?

NO

STEP 10.9

YES

COMPUTE COORDINATE NUMBERS FOR R.H. END OF ELEMENT AND ASSIGN COORDINATE VALUES.
SET LA = 1

NO

GOTO STEP 10.14

GOTO STEP 10.14

FLOW CHART: SUBPROGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)
Appendix C

A)

COMPUTE PARTITIONED STIFFNESS MATRIX FOR ELEMENT SUBROUTINE ELEM

STEP 10.10

COMPUTE INITIAL VALUES OF SHEAR, SHRI, AND BENDING MOMENT, BNDI, DUE TO ELASTIC DEFORMATION

STEP 10.11

COMPUTE PARTITIONED MASS MATRIX FOR ELEMENT SUBROUTINE ELEM

STEP 10.12

COMPUTE INERTIA RELIEF FOR SHEAR AND BENDING MOMENT AND ADD TO PREVIOUS VALUES OF SHEAR AND BENDING MOMENT

STEP 10.13

INITIALIZE PARAMETERS
SET LC = LA

STEP 10.14

SET ELEMENT NUMBER WITHIN BAY
K = 1, NLMT

STEP 10.15

YES

K ≤ 1

NO

YES

XS = X1(CNT+1)

NO

XS = X1(CNT)

STEP 10.16

LA = 1

STEP 10.17

GØ TØ STEP 10.21.1

STEP 10.18

COMPUTE COORDINATE NUMBERS FOR ELEMENT

B

FLOW CHART: SUBPROGRAM SSBM (NCØ, NBAY, NSUP, IBL, NINT, NDATA)
Appendix C

STEP 10.19.1
THE LAST GRID POINT HAS BEEN ENCOUNTERED.
SET COORDINATE VALUES AT R.H. END OF ELEMENT.

STEP 10.19.2
SET COORDINATE VALUES AT EACH END OF THE ELEMENT

STEP 10.20
IS THE COORDINATE POINT ELASTICALLY SUPPORTED?

STEP 10.21.1
COMPUTE SUPPORT (POINT) SHEAR AND BENDING MOMENT IMPEDANCE AND ADD TO CURRENT VALUES

STEP 10.21.2
SET POINT SHEAR AND BENDING MOMENT EQUAL TO CURRENT VALUES

BEGIN INTERPOLATION OVER ELEMENT
JJ = 1, NINT

STEP 10.22
SET INDEX, CNT
SET DIMENSIONLESS COORDINATE, ZE
SET LOCAL COORDINATE, X
X1 = X + XS

STEP 10.23
COMPUTE VALUES OF
W(CNT) EQN. 16*
DW(CNT) EQN. 16*
SHR(CNT) EQN. 17*
BND(CNT) EQN. 18*

STEP 10.24
SET LA = 0
CURRENT VALUE OF SHEAR = SHR(CNT)
CURRENT VALUE OF BENDING MOM. = BND(CNT)

*Reference 1, p. 10

FLOW CHART: SUBPROGRAM SSBM (NC0, NBAY, NSUP, IBL, NINT, NDATA)
Appendix C

**Flow Chart: Subprogram SSBM (NC0, NBAY, NSUP, IBL, NINT, NDATA)**

```
C

YES

JJ ≥ NINT

NØ

STEP 10.26

YES

K ≥ NLMT

NØ

STEP 10.27

STEP 10.28

NCUR = IC + 1

YES

J ≥ NBAY

NØ

STEP 10.29

STEP 10.30

YES

INITIALIZE NORMALIZING VALUES
WMAX, DWMAX, SHRMAX, BNDMAX
SET UPPER LIMIT ON VALUES
COMPUTED

STEP 10.31

SEARCH ARRAYS W(IW), WD(IW)
SHR(IW), BND(IW) AND SELECT
MAXIMUM VALUES, WMAX, ETC.

STEP 10.32

COMPUTE NORMALIZED VALUES
W(IM) = W(IM)/WMAX
ETC.

STEP 10.33

FOR EACH BAY PRINT VALUES FOR LOCATION
IN BAY, X1(IR), AND NORMALIZED VALUES
FOR W(IR), DW(IR), SHR(IR), BND(IR)

STEP 10.34

YES

STEP 10.35

RETURN

GØ TO STEP 10.2
```
SUBROUTINE SSBM(NCO, NS, IBL, NINT, NDATA)

DIMENSION EVL(38), EVC(1156), W(5), BLMT(5)

DIMENSION SL(6), SC(6), SR(6), RL(6), RC(6), RR(6)

DIMENSION NEL(5), NCP(6), S1(4), S2(4), S3(4)

DIMENSION DUM1(293), DUM2(5)

DIMENSION XI(180), W(180), DW(180), SHR(180), BND(180)

COMMON EVL, EVC, DUM1, W, BLMT, BW, DUM2

COMMON TL, SL, SC, SR, RL, RC, RR, NEL, NCP

COMMON DUM3, S1, S2, S3, XI, W, DW, SHR, BND

INTEGER CNT

IO=6

STP=1./FLOAT(NINT)

NINT=NINT+1

DO 1 929 I=1,15

WRITE(IO,100)

WRITE(IO,101) NDATA

SHR=0

BDP=0

SLP=0

BDP=0

NLMAX=0

CNT=0

NN=NCO+1-1

WRITE(IO,102) EVL(NN)

NFL=NN*NCO-1

OM=6.28316*EVL(NN)

OMS=OM*OM

NCUR=0

LA=0

DO 921 J=1, NS

NLMT=NEL(J)

NLMAX=NLMAX+NLMT

BRM=OMS*W(B(J))/386.

IF(J-1) 901, 901, 902

901 IF(IBL-I) 907, 902, 902

902 K1=NC0*(NN-1)+1

K2=K1+1

D1=0

D2=0

D3=EVC(K1)

D4=EVC(K2)

LA=1

CALL ELEM(J,1,S1,S2,S3)

SHRI=S2(1)*TL*D3+S2(3)*D4

BDP=S2(2)*TL*D3-S2(4)*D4

CALL ELEM(J,2,S1,S2,S3)

SHRI=SHRI-OMS*S2(1)*TL*D3-OMS*S2(3)*D4

BDP=BDP+OMS*S2(2)*TL*D3+OMS*S2(4)*D4

907 CONTINUE

X1(CNT+1)=0.

LC=LA

DO 920 K=1, NLMT

IF(K=1) 903, 903, 904

903 X5=X1(CNT+1)

GO TO 905

904 X5=X1(CNT)

905 IF(1-LA) 908, 914, 908

SUBPROGRAM SSBM: CARD IMAGE LISTING 1/3
IC = NCUR + 2*K - 2*LC - 1
K1 = NC0*(NN-1) + IC
K2 = K1 + 1
K3 = K1 + 2
K4 = K1 + 3
IF(KI = NFL) 909, 910, 910
909 D1 = EVC(K1)
D2 = EVC(K2)
D3 = EVC(K3)
D4 = EVC(K4)
90 TO 911
910 D1 = EVC(K1)
D2 = EVC(K2)
D3 = 0.
D4 = 0.
911 DO 912 KK = 1, NSUP
IF(NCP(KK) = IC) 912, 913, 912
912 CONTINUE
90 TO 914
913 SHRP = (OMS * RL(KK) / 386 - SL(KK)) * TL*D1 +
2*(OMS * RC(KK) / 386 - SC(KK)) * D2 + SHRI
BDP = (SC(KK) - OMS * RC(KK) / 386.0) * TL*D1 +
2*(EVC(KK) - OMS * RR(KK) / 386.0) * D2 + BNDI
90 TO 915
914 SHRP = SHRI
BDP = BNDI
915 CONTINUE
DO 920 JJ = 1, NINT
CNT = CNT + 1
T = STP * FLOAT(JJ - 1)
X = X1*(BLMT(J))
X1(CNT) = X + XS
ZES = ZE + ZE
ZEC = ZES + ZE
W(CNT) = (ZES - ZEC - 3**ZES + 1.0) * TL*D1 + X*(ZES - 2**ZE + 1.0) * D2 -
2*(ZES - 1**ZEC - 3**ZES + 1.0) * TL*D3 + X*ZEC - 2**ZES + 1.0) * D4
D1(CNT) = 6.0**ZE - (ZE - 1.0) * TL*D1 / BLMT(J) + (3.0**ZES - 4**ZE + 1.0) * D2 -
2*(ZES - 1**ZEC - 3**ZES + 1.0) * TL*D3 / BLMT(J) + ZE*(3.0**ZES - 2.0) * D4
SHR(CNT) = SHRP + BMM**X*(1.5**ZEC - ZES + 1.0) * TL*D1 +
2*BMM**X*(2.5**ZES - 2.0**ZEC - 3**ZES + 5.0) * D2 -
3*BMM**X*(5.0**ZEC - ZE - 1.0) * TL*D3 +
4*BMM**X*(2.5**ZEC - 1.0/3.0) * D4
BND(CNT) = BDP + SHRP**X + BMM**X*(1.0**ZEC - 2.5**ZES + 5.0) * TL*D1 +
2*BMM**X*(0.05**ZES - ZE/6.0 + 1.0/6.0) * D2 -
3*BMM**X*(1.0**ZEC - 2.5) * TL*D3 +
4*BMM**X*(1.0**ZEC - ZE/6.0 + 1.0/12.0) * D4
LA = 0
SHR1 = SHR(CNT)
BND = BND(CNT)
920 CONTINUE
NCUR = IC + 1
921 CONTINUE
WMAX = 0.
D1MAX = 0.
SHRMAX = 0.
BNDMAX = 0.
LIMENL = MAX*NINT
DO 924 IW = 1, LIM
IF(ABS(W(IW)) - WMAX) 916, 916, 917
SUBPROGRAM SSBM: CARD IMAGE LISTING 2/3
917 WMAX=ABS(W(IW))
918 IF(ABS(DW(IW))=DWMAX) 918,918,919
919 DWMAX=ABS(DW(IW))
920 IF(ABS(SHR(IW))=SHRMAX) 922,922,923
923 SHRMAX=ABS(SHR(IW))
924 CONTINUE
925 BNDMAX=ABS(BND(IW))
926 CONTINUE
927 CONTINUE
928 CONTINUE
929 CONTINUE
930 FORMAT(1H1)
931 FORMAT(25X,9HDATA CASE,I4)
932 FORMAT(/,5X,1HFREQUENCY =,F12.5,1X,3HZ.)
933 FORMAT(/,29X,3HBAY,I2)
934 FORMAT(/,9X,1HX,10X,1HW,8X,5HDW/1X,9X,1HV,11X,1HM)
935 RETURN
936 END.

SUBPROGRAM SSBM: CARD IMAGE LISTING 3/3
Appendix C

SEGMENr LEVEL
LEVEL 1

MAIN PROGRAM
PLTVIB

COMPUTE AND ASSEMBLE STIFFNESS MATRIX

SEGMENT 1
RDNWRT

SEGMENT 2
PLTSTF

SEGMENT 5
RIB, ASSYR

SEGMENT 6
NONDIM, ORDER, FILL, DELETE

SEGMENT 4
PLTMAS

SEGMENT 3
ASSYP

SEGMENT 3
ASSYP

SEGMENT 1
RDNWRT

SEGMENT 7
NROOT, EIGEN

SEGMENT 1
RDNWRT

SEGMENr LEVEL
LEVEL 2

COMPUTE AND ASSEMBLE MASS MATRIX

COMPUTE AND PRINT EIGENVALUES AND EIGENVECTORS

TWO-DIMENSIONAL PANEL ANALYSIS:
PROGRAM CORE-OVERLAY STRUCTURE
PROGRAM PLTVIB (MAIN)
(See Figure 2 for Flow Chart)

PURPOSE: Main program for computing the natural frequencies and normal mode shapes of a nine-bay orthogonally stiffened flat panel. The structure is assumed to have clamped edges along the edges and four orthogonal stiffeners dividing the uniform cover sheet into nine bays. The stiffeners are modeled with a finite element representation of a thin-walled open-section beam. The stiffener element deformation fully conforms to the plate element deformation along the edges of the plate element. The rectangular plate bending element used is based upon a sixteen degree-of-freedom element with an interior element mode in the form of a clamped-clamped beam fundamental mode.

SUBPROGRAMS REQUIRED: RDNWRT, PLTSTF, PLTMAS, RIB, NONDIM, ASSYR, ASSYP, FILL, ZERO, ORDER, DELETE*, LOC*, EIGEN*, NROOT*

INPUT DATA: See Appendix D for description - NCASE, A(I), B(I), EP, HP, PR, RHOP, ER(I), GR(I), RH0(I), SR2(I), C2(I), SR3(I), C3(I), AR(I), A22(I), A23(I), A33(I), SJ(I), RE2(I), RE3(I), GM(I)

VARIABLES: NDEL(D) - Constraint vector for an N degree-of-freedom system. If NDEL(R) = 1 the Rth coordinate is removed from the equations of motion. If NDEL(R) = 0, the Rth coordinate is ignored in subprogram ORDER.
S1(I), S2(I), S3(I) - The arrays represented the partitioned stiffness or mass matrices of the plate on rib element.
SC(D) - The coupling term between the edge displacements and the generalized coordinate for the plate stiffness and mass matrices.
SF(I), RF(I) - Structure stiffness and mass matrices (symmetric storage mode: LOC)
EVL(I) - Array of eigenvalues
Appendix C

VARIABLES:  
(Continued)  
EVC(I) - Array of eigenvectors  
R(I) - Dummy array  
M - Number of grid points in f-direction  
N - Number of grid points in y-direction  

RESTRICTIONS:  
For the declared size of the arrays: M \leq 4, N \leq 4  

ACCURACY:  
Not Applicable  

SIZE: 0063718  

REFERENCES:  
Reference 1, pp. 11 - 16  

*Subroutine is identical to that described for the one-dimensional analysis.
SEGZERO(SEG0, PLTVIB, LOC, ZERO)
SEGMENT(SEG1, RDNWRT)
SEGMENT(SEG2, PLTSTF)
SEGMENT(SEG3, ASSYP)
SEGMENT(SEG4, PLTMAS)
SEGMENT(SEG5, RIB, ASSYR)
SEGMENT(SEG6, NONDIM, ORDER, FILL, DELETE)
SEGMENT(SEG7, NROOT, EIGEN)

PROGRAM PLTVIB (INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT)
COMMON ER(4), GR(4), RH0(4), SR2(4)*C2(4), SR3(4)*C3(4),
COMMON R(2701), A(3), B(3)
COMMON NCAE, EP, HP, PR, RHOP, DP, TL, TK, TM, NCO
DIMENSION NDEL(73), S1(36), S2(64), S3(36), SC(17),
SF(25), RF(25), EVL(25), EVC(25), ANAME(2)
EQUIVALENCE (R(326), RF(1)), (R(952), EVC(1))
DATA LFILE/3HLG0/

IDATA=1
100 READ(5, 105) NDATA
105 FORMAT(5X, I3)
110 M=4

N=4
NC=4
MBAY=M-1
NBAY=N-1
NGP=M*N
NU1=NC*NGP
NCO=NU1+MBAY*NBay
ANAME(1)=4HSEG1
ANAME(2)=0
CALL SEGMENT(LFILE, 1, ANAME)
CALL RDNWRT(1)
C INITIALIZE CONSTRAINT VECTOR

DO 120 I=1, 64
111 IF(I-20) 115, 115, 111
112 IF(I-29) 114, 115, 112
113 IF(I-36) 115, 115, 113
114 NDEL(I)= 0
GO TO 120
115 NDEL(I)= 1
120 CONTINUE
TL= SQRT(A(2)*A(2)+B(2)*B(2))
DP=EP*HP*HP*HP/(12*(1-PR*PR))
CALL RDNWRT(2)
RHOP=RHOP*HP/386.
NU1=NC*NGP
DO 305 IOP=1, 2
NCO=NU1+MBAY*NBay
CALL ZERO(QR, 2701)
IF(IOP=1) 200, 200, 210
C COMPUTE AND ASSEMBLE FREE-FREE PLATE STIFFNESS MATRIX
200 ANAME(1)=4HSEG2
ANAME(2)=0

PROGRAM PLTVIB: CARD IMAGE LISTING 1/3
CALL SEGMENT(LFILE,1,ANAME)
ANAME(1)=4HSEG3
ANAME(2)=0
CALL SEGMENT(LFILE,2,ANAME)
DO 205 J=1,NBAY
DY=B(J)
DO 205 I=1,MBAY
DX=A(I)
CALL PLTSTF(DX, DY, DP, PR, S1, S2, S3, SC)
CALL ASSYR(R, S1, S2, S3, SC, I, M, J, N, NCP)
205 CONTINUE

C COMPUTE AND ASSEMBLE FREE-FREE PLATE MASS MATRIX
210 ANAME(1)=4HSEG4
ANAME(2)=0
CALL SEGMENT(LFILE,1,ANAME)
ANAME(1)=4HSEG3
ANAME(2)=0
CALL SEGMENT(LFILE,2,ANAME)
DO 215 J=1,NBAY
DY=B(J)
DO 215 I=1,MBAY
DX=A(I)
CALL PLTMAS(DX, DY, RHOP, S1, S2, S3, SC)
CALL ASSYR(R, S1, S2, S3, SC, I, M, J, N, NCP)
215 CONTINUE

C COMPUTE AND ASSEMBLE FREE-FREE RIB STIFFNESS AND MASS MATRICES
220 ANAME(1)=4HSEG5
ANAME(2)=0
CALL SEGMENT(LFILE,1,ANAME)
DO 270 IR=1,4
GO TO (225, 235, 250, 255), IR
225 J=2
GO TO 240
235 J=3
240 AX=1.0
DO 245 I=1,MBAY
DR=A(I)
CALL RIB(IR, IOP, DR, S1, S2, S3)
CALL ASSYR(R, S1, S2, S3, I, M, J, N, NCP, AX)
245 CONTINUE
GO TO 270
250 I=2
GO TO 260
255 I=3
260 AX=0.0
DO 265 J=1,NBAY
DR=B(J)
CALL RIB(IR, IOP, DR, S1, S2, S3)
CALL ASSYR(R, S1, S2, S3, I, M, J, N, NCP, AX)
265 CONTINUE

C NONDIMENSIONALIZE MATRICES
TR=0.0

PROGRAM PLTVIB: CARD IMAGE LISTING 2/3
PROGRAM PLTVIB: CARD IMAGE LISTING 3/3
SUBROUTINE RDNWRT (ITØ)

PURPOSE: This subprogram contains all input/output statements for program PLTVIB. Input data definition and format is described in Appendix D. An example of output format is also included.

SUBPROGRAMS REQUIRED: None

VARIABLES: ITØ

= 1, input data read
= 2, edited input data is printed
= 3, NCASE, TK, TL, TM are printed
= 4, eigenvalues and eigenvectors are printed

NCASE Four digit data identification number

TK, TL, TM Nondimensionalizing constants for force (stiffness), length, and mass, respectively

RESTRICTIONS: 1 ≤ ITØ ≤ 4

ACCURACY: Not Applicable

SIZE: 001026

REFERENCES: None
FLOW CHART: SUBROUTINE RDNWRT(ITO)
SUBROUTINE RDNWRT (ITO)
COMMON ER(4), GR(4), RH0(4), SR2(4), C2(4), SR3(4), C3(4), 
COMMON R(2701), A(3), B(3)
COMMON NCASE, EP, HP, PR, RH0P, DP, TL, TK, TM, NCO
DIMENSION EyL(25), EyC(b25), RF(625)
EQUIVALENCE (R(32), RFU), (R(95), EVi (1)), MR(978), EVC(D)

IN=5
IO=6
GO TO (100, 200, 300, 400, 500) ITO

READ(IN, 600) NCASE
READ(IN, 605) A(1), A(2), A(3)
READ(IN, 605) B(1), B(2), B(3)
READ(IN, 610) EP, HP, PR, RH0P
DO 105 I=1, 4
READ(IN, 610) ER(I), GR(I), RH0(I)
READ(IN, 610) SR2(I), C2(I), SR3(I), C3(I)
READ(IN, 610) AR(I), A22(I), A23(I), A33(I)
READ(IN, 610) SJ(I), RE2(I), RE3(I), GM(I)
CONTINUE
RETURN

WRITE(IO, 620) NCASE
WRITE(IO, 625)
WRITE(IO, 630) A(1), A(2), A(3)
WRITE(IO, 640)
WRITE(IO, 650)
DO 140 I=1, 4
GO TO (130, 130, 135, 135) I

WRITE(IO, 655)
WRITE(IO, 660) I, ER(I), GR(I), RH0(I)
WRITE(IO, 665) SR2(I), C2(I), SR3(I), C3(I)
WRITE(IO, 670) AR(I), A22(I), A23(I), A33(I)
WRITE(IO, 675) SJ(I), RE2(I), RE3(I), GM(I)
GO TO 140

WRITE(IO, 680)
WRITE(IO, 660) I, ER(I), GR(I), RH0(I)
WRITE(IO, 685) SR2(I), C2(I), SR3(I), C3(I)
WRITE(IO, 690) AR(I), A22(I), A23(I), A33(I)
WRITE(IO, 695) SJ(I), RE2(I), RE3(I), GM(I)
CONTINUE
RETURN

WRITE(IO, 620) NCASE
WRITE(IO, 700)
WRITE(IO, 705) TK, TL, TM
RETURN

DO 415 I=1, NCO
IF(EVL(I)) 405, 410, 410

EVl(I) = ABS(EVL(I))
FREQ = 0.159155*SQRT(TM/ER(I))
WRITE(IO, 710) EVL(I), FREQ
WRITE(IO, 715)
IX=NCO*(I-1)+1
IY=NCO*I
WRITE(IO, 720) (EVC(J), J=IX, IY)
CONTINUE
RETURN

FORMAT(5X, 14)
SUBROUTINE PLTSTF (A, B, D, P, S1, S2, S3, SC)

PURPOSE: To compute the stiffness matrix of the modified sixteen degree-of-freedom plate element described by Bogner, Fox, and Schmidt with an interior mode in the form of clamped-clamped beam functions.

SUBPROGRAMS REQUIRED: None

VARIABLES: A - Dimension of the plate element in the x-direction
B - Dimension of the plate element in the y-direction
D - Bending rigidity of plate element (Reference 1)
P - Poisson's ratio for the plate element
S1, S2, S3, SC - Partitioned stiffness matrices for the plate element

(see Flow Chart and Appendix B)

RESTRICTIONS: A ≠ 0, B ≠ 0

ACCURACY: See References below

SIZE: 0022208

REFERENCES:
- Reference 1, pp. 12 - 15
BEGIN

COMPUTE ASPECT RATIO PARAMETERS

FILL ARRAY S1(I)*

$S1(I) = \begin{bmatrix} K_{11} & K_{12} \\ \text{sym.} & K_{22} \end{bmatrix}$

FILL ARRAY S2(I)*

$S2(I) = \begin{bmatrix} K_{13} & K_{14} \\ K_{23} & K_{24} \end{bmatrix}$

FILL ARRAY S3(I)*

$S3(I) = \begin{bmatrix} K_{33} & K_{34} \\ \text{sym.} & K_{44} \end{bmatrix}$

FILL ARRAY SC(I)*

$SC(I) = \begin{bmatrix} K_{ci} \end{bmatrix}$

$SC(17) = k$

MULTIPLY ALL VALUES BY $D/ab$

RETURN

*SEE APPENDIX B

FLOW CHART: SUBROUTINE PLTSTF (A, B, D, P, S1, S2, S3, SC)
Appendix C

SUBROUTINE PLTSTF(A,B,D,P,S1,S2,S3,SC)

DIMENSION S1(2),S2(2),S3(2),SC(2)

A=B=A

F= B*B/(A*A)

G= A*A/(B*B)

R= F+G

C0= 39647605

C1= 20771538

C2= 9469616

C3= 6472757

PHI=R+2.*C11*C11*(C31-2.)*(C31-2.)

SM= C0*C0*PHI/(C21*C21)

SM1=SM/2048.-C0*C11*C11

SM2=SM/4096.-C0*C11*C11

S1(1)= 158.*R/35.+2.*R88.+0625*SM

S1(2)= (22.*F+78.*G)/35.+1.2*(2.*P)+015625*SM)*B

S1(3)= (4.*F+52.*G)/35.+32.+00390625*SM)*B

S1(4)= -(78.*F+22.*G)/35.+1.2*(2.*P)+015625.*SM)*A

S1(5)= -(11.1*R/35.+02*1.2*P-0.00390625*SM)*AB

S1(6)= (52.*F+4.*G)/35.+32.+00390625*SM)*A

S1(7)= (11.1*R/35.+02*1.2*P+8.*SM1)*AB

S1(8)= (2.2*R+22.*G/3.)/.35.+2.*R*.2*P/15.+2.*SM1)*AB

S1(9)= -(22.*F/3.+2.*G)/35.+2.*R*.2*P/15.+2.*SM1)*A

S1(10)= (4.*R/105.+8.*225.+SM2)*AB*AB

S1(11)= (196.*F=54.*G)/35.-2.88.*0625*SM

S1(12)= (122.*F-27.*G)/35.+2.*P+015625*SM)*B

S1(13)= (78.*F=13.*G)/35.+24.-015625*SM)*A

S1(14)= (11.*F=6.5.*G)/35.+1*(2.*P)-R.*SM1)*AB

S1(15)= S1(1)

S1(16)= S1(12)

S1(17)= (4.*F=18.*G)/35.+32.-00390625*SM)*B

S1(18)= (11.*F=6.5.*G)/35.+1*(2.*P)+00390625*SM)*AB

S1(19)= (2.2*F-13.*G/3.)/.35.+2.75.-2.*SM)*AB

S1(20)= S1(2)

S1(21)= S1(3)

S1(22)= S1(13)

S1(23)= S1(18)

S1(24)= (26.*F-3.*G)/35.-.08.-00390625*SM)*A

S1(25)= (61.*F/3.-1.5.*G)/35.-.32+0.00390625*SM)*A

S1(26)= S1(4)

S1(27)= S1(5)

S1(28)= S1(6)

S1(29)= S1(14)

S1(30)= S1(19)

S1(31)= S1(25)

S1(32)= (2.*F/3.-G)/35.-2.*225.-SM2)*AB*AB

S1(33)= S1(7)

S1(34)= S1(8)

S1(35)= S1(9)

S1(36)= S1(10)

S2(1)= (54.*F-156.*G)/35.-2.88.*0625*SM

S2(2)= (13.*F-78.*G)/35.-.24+.015625*SM)*B

S2(3)= -(27.*F-22.*G)/35.-1.2*(2.*P)+.015625*SM)*A

S2(4)= -(6.5.*F-11.*G)/35.-1.*(2.*P)+R.*SM1)*AB

S2(5)= -54.*R/35.+2.88.+0625*SM

S2(6)= -(13.*F-27.*G)/35.-.24-.015625*SM)*B

S2(7)= -(127.*F+13.*G)/35.-.24-.015625*SM)*A

S2(8)= (6.5.*R/35.-.02*8.*SM1)*AB

SUBPROGRAM PLTSTF: CARD IMAGE LISTING 1/3
\[ S_2(9) = -S_2(2) \]
\[ S_2(10) = ((3.6F - 26.6G)/35.2 + 25.2 + 0.00390625*SM)B*B \]
\[ S_2(11) = ((6.5F - 11.6G)/35.2 + 1.2 + P + 0.00390625*SM)A*B \]
\[ S_2(12) = ((1.5F - 11.6G/3.1)/35.2 + 1.2 + P)/30.1 + 2.0*SM)*A*B \]
\[ S_2(13) = -S_2(6) \]
\[ S_2(14) = ((3.6F + 9.6G)/35.2 + 0.08 + 0.00390625*SM)*B*B \]
\[ S_2(15) = (6.5R/35.2 + 0.02 + 0.00390625*SM)A*B \]
\[ S_2(16) = ((1.5F + 13.6G/6.1)/35.2 + 1.2 + 15.0 + 2.0*SM)*A*B \]
\[ S_2(17) = S_2(3) \]
\[ S_2(18) = -S_2(11) \]
\[ S_2(19) = ((18.6F - 4.6G)/35.2 + 32 + 0.00390625*SM)*A*A \]
\[ S_2(20) = ((13.6F - 3.2G)/35.2 + 2.75 + 2.0*SM)*A*A \]
\[ S_2(21) = -S_2(7) \]
\[ S_2(22) = -S_2(15) \]
\[ S_2(23) = (19.6F + 3.6G)/35.2 + 0.08 + 0.00390625*SM)*A*A \]
\[ S_2(24) = ((13.6F + 1.5G)/35.2 + 1.2 + 15.0 + 2.0*SM)*A*A \]
\[ S_2(25) = -S_2(4) \]
\[ S_2(26) = S_2(12) \]
\[ S_2(27) = -S_2(20) \]
\[ S_2(28) = (F - 2.6G/3.1)/35.2 + 2.25 + 2.0*SM)*A*B \]
\[ S_2(29) = S_2(8) \]
\[ S_2(30) = -S_2(16) \]
\[ S_2(31) = -S_2(24) \]
\[ S_2(32) = (R/70.1 + 1.0/450) - AB*AB \]
\[ S_2(33) = S_2(5) \]
\[ S_2(34) = S_2(6) \]
\[ S_2(35) = -S_2(7) \]
\[ S_2(36) = -S_2(8) \]
\[ S_2(37) = -S_2(1) \]
\[ S_2(38) = S_2(12) \]
\[ S_2(39) = S_2(3) \]
\[ S_2(40) = -S_2(4) \]
\[ S_2(41) = S_2(13) \]
\[ S_2(42) = -S_2(14) \]
\[ S_2(43) = -S_2(15) \]
\[ S_2(44) = -S_2(16) \]
\[ S_2(45) = S_2(9) \]
\[ S_2(46) = S_2(10) \]
\[ S_2(47) = -S_2(11) \]
\[ S_2(48) = S_2(12) \]
\[ S_2(49) = -S_2(35) \]
\[ S_2(50) = S_2(43) \]
\[ S_2(51) = S_2(23) \]
\[ S_2(52) = S_2(24) \]
\[ S_2(53) = -S_2(17) \]
\[ S_2(54) = -S_2(18) \]
\[ S_2(55) = S_2(19) \]
\[ S_2(56) = S_2(20) \]
\[ S_2(57) = -S_2(29) \]
\[ S_2(58) = S_2(30) \]
\[ S_2(59) = S_2(31) \]
\[ S_2(60) = S_2(32) \]
\[ S_2(61) = -S_2(15) \]
\[ S_2(62) = S_2(26) \]
\[ S_2(63) = S_2(27) \]
\[ S_2(64) = S_2(26) \]
\[ S_3(1) = S_1(1) \]
\[ S_3(2) = -S_1(2) \]
\[ S_3(3) = S_1(3) \]
<table>
<thead>
<tr>
<th>Appendix C</th>
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<tbody>
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<tr>
<td>[ S_{c1}(1) = -25*SM ]</td>
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<tr>
<td>[ S_{c1}(2) = -0.0625<em>SM</em>AB ]</td>
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<tr>
<td>[ S_{c1}(3) = -0.0625<em>SM</em>A ]</td>
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<td>[ S_{c1}(4) = -32<em>SM1</em>AB ]</td>
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<td>[ S_{c1}(7) = -SC(3) ]</td>
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<td>[ S_{c1}(9) = -25*SM ]</td>
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<td>[ S_{c1}(10) = -SC(2) ]</td>
</tr>
<tr>
<td>[ S_{c1}(11) = -0.0625<em>SM</em>A ]</td>
</tr>
<tr>
<td>[ S_{c1}(12) = 32<em>SM1</em>AB ]</td>
</tr>
<tr>
<td>[ S_{c1}(13) = -25*SM ]</td>
</tr>
<tr>
<td>[ S_{c1}(14) = -0.0625<em>SM</em>AB ]</td>
</tr>
<tr>
<td>[ S_{c1}(15) = -0.0625<em>SM</em>A ]</td>
</tr>
<tr>
<td>[ S_{c1}(16) = -32<em>SM1</em>AB ]</td>
</tr>
<tr>
<td>[ S_{c1}(17) = SM ]</td>
</tr>
<tr>
<td>[ DO 25 I=1,64 ]</td>
</tr>
<tr>
<td>[ IE(I=17)55510 ]</td>
</tr>
<tr>
<td>[ 5 SC(I) = D*SC(I)/AB ]</td>
</tr>
<tr>
<td>[ 10 IE(I=36)151520 ]</td>
</tr>
<tr>
<td>[ 15 S1(I) = D*S1(I)/AB ]</td>
</tr>
<tr>
<td>[ S3(I) = D*S3(I)/AB ]</td>
</tr>
<tr>
<td>[ 20 S2(I) = D*S2(I)/AB ]</td>
</tr>
<tr>
<td>[ 25 CONTINUE ]</td>
</tr>
<tr>
<td>[ RETURN ]</td>
</tr>
</tbody>
</table>

SUBPROGRAM PLTSTF: CARD IMAGE LISTING 3/3
SUBROUTINE PLTMAS (A, B, R, S1, S2, S3, SC)

PURPOSE: To compute the consistent mass matrix of the modified sixteen degree-of-freedom plate element described by Bogner, Fox, and Schmidt with an interior mode in the form of clamped-clamped beam functions.

SUBPROGRAMS REQUIRED: None

VARIABLES: A - Dimension of the plate element in the x-direction
B - Dimension of the plate element in the y-direction
R - Mass per unit area of plate element
S1, S2, S3, SC - Partitioned mass matrices for the plate element (see Flow Chart and Appendix B)

RESTRICTIONS: None

ACCURACY: See References below

SIZE: 001520₈

REFERENCES: See References for subroutine PLTSTF
Appendix C

FLOW CHART: SUBROUTINE PLTMAS (A, B, R, S1, S2, S3, SC)

*SEE APPENDIX B
SUBROUTINE PLTMAS(A,B,R,S1,S2,S3,SC)

DIMENSION S1(2),S2(2),S3(2),SC(2)

A=B*6

C1 = .13./35.
C2 = .11./210.
C3 = .1./105.
C4 = .9./70.
C5 = .13./420.
C6 = .1./140.
C0 = .39647605
C11 = .20771538
C21 = .40469616
C31 = 4.6472757

R1 = C0*(-.0625*C0-.2*C11*C11)
R2 = C0*(-.015625*C0-C11*(C21+.25*C11))
R3 = C0*(-.00390625*C0-.5*C11*C21)
R4 = C0*(-.00390625*C0-C21*C21-.0625*C11*C11)
R5 = C0*(C0/1024.*.25*C21*(C21+.25*C11))
R6 = C0*(C0/4096.*.125*C21*C21)
R7 = C0*(.25*C0-4.*C11*C11)
R8 = C0*(-.0625*C0-4.*C11*C21)
R9 = C0*(-.015625*C0-.4*C11*C21)

S1(1) = C1*C1*R1
S1(2) = (C1*C2+R2)*B
S1(3) = (C1*C3+R3)*B*B
S1(4) = -(C1*C2+R2)*A
S1(5) = -(C2*C2+R3)*AB
S1(6) = (C1*C3+R3)*A*A
S1(7) = (C2*C2+R4)*AB
S1(8) = (C2*C3+R5)*AB*B
S1(9) = -(C2*C3+R5)*A*AB
S1(10) = (C3*C3+R6)*AB*AB
S1(11) = C1*C4*R1
S1(12) = (C2*C4+R2)*B
S1(13) = (C1*C5+R2)*A
S1(14) = (C2*C5+R4)*AB
S1(15) = S1(1)
S1(16) = S1(12)
S1(17) = (C3*C4+R3)*B*B
S1(18) = (C2*C5+R3)*AB
S1(19) = (C3*C5+R5)*AB*B
S1(20) = S1(2)
S1(21) = S1(13)
S1(22) = S1(11)
S1(23) = S1(18)
S1(24) = (C1*C6+R3)*A*A
S1(25) = (C2*C6+R5)*A*AB
S1(26) = S1(4)
S1(27) = S1(15)
S1(28) = S1(6)
S1(29) = S1(14)
S1(30) = S1(19)
S1(31) = S1(25)
S1(32) = (C3*C6+R6)*AB*AB
S1(33) = S1(7)
S1(34) = S1(8)
S1(35) = S1(9)
S1(36) = S1(10)
Appendix C

\[ S_2(1) = C_1C_4 + R_1 \]

\[ S_2(2) = (C_1C_5 + R_2) * B \]

\[ S_2(3) = -(C_2C_4 + R_2) * A \]

\[ S_2(4) = (C_2C_5 + R_4) * AB \]

\[ S_2(5) = C_4C_4 + R_1 \]

\[ S_2(6) = (C_4C_5 + R_2) * B \]

\[ S_2(7) = (C_4C_5 + R_2) * A \]

\[ S_2(8) = -(C_5C_5 + R_4) * AB \]

\[ S_2(9) = -S_2(2) \]

\[ S_2(10) = -(C_1C_6 + R_3) * B * B \]

\[ S_2(11) = (C_2C_5 + R_3) * AB \]

\[ S_2(12) = -(C_2C_6 + R_5) * AB * B \]

\[ S_2(13) = -S_2(6) \]

\[ S_2(14) = (C_4C_6 + R_3) * B * B \]

\[ S_2(15) = -(C_5C_5 + R_3) * AB \]

\[ S_2(16) = (C_5C_6 + R_5) * AB * B \]

\[ S_2(17) = S_2(3) \]

\[ S_2(18) = -S_2(11) \]

\[ S_2(19) = (C_3C_4 + R_3) * A * A \]

\[ S_2(20) = -(C_3C_5 + R_5) * A * AB \]

\[ S_2(21) = -S_2(7) \]

\[ S_2(22) = -S_2(15) \]

\[ S_2(23) = -(C_4C_6 + R_3) * A * A \]

\[ S_2(24) = -(C_5C_6 + R_5) * A * AB \]

\[ S_2(25) = -S_2(4) \]

\[ S_2(26) = -S_2(12) \]

\[ S_2(27) = -S_2(20) \]

\[ S_2(28) = -(C_3C_6 + R_6) * AB * AB \]

\[ S_2(29) = S_2(8) \]

\[ S_2(30) = -S_2(16) \]

\[ S_2(31) = -S_2(24) \]

\[ S_2(32) = -(C_6C_6 + R_6) * AB * AB \]

\[ S_2(33) = S_2(5) \]

\[ S_2(34) = S_2(6) \]

\[ S_2(35) = -S_2(7) \]

\[ S_2(36) = -S_2(8) \]

\[ S_2(37) = S_2(1) \]

\[ S_2(38) = -S_2(2) \]

\[ S_2(39) = -S_2(3) \]

\[ S_2(40) = -S_2(4) \]

\[ S_2(41) = S_2(13) \]

\[ S_2(42) = -S_2(14) \]

\[ S_2(43) = -S_2(15) \]

\[ S_2(44) = -S_2(16) \]

\[ S_2(45) = S_2(9) \]

\[ S_2(46) = -S_2(10) \]

\[ S_2(47) = -S_2(11) \]

\[ S_2(48) = -S_2(12) \]

\[ S_2(49) = -S_2(21) \]

\[ S_2(50) = -S_2(22) \]

\[ S_2(51) = S_2(23) \]

\[ S_2(52) = -S_2(24) \]

\[ S_2(53) = -S_2(17) \]

\[ S_2(54) = -S_2(18) \]

\[ S_2(55) = -S_2(19) \]

\[ S_2(56) = -S_2(20) \]

\[ S_2(57) = -S_2(29) \]

\[ S_2(58) = -S_2(30) \]

\[ S_2(59) = S_2(31) \]
IF(I-17) 5*5*10
5  SC(I)= R*SC(I)*AB
10 IF(I-36) 15,15,20
15  S1(I)= R*S1(I)*AB
20  S3(I)= R*S3(I)*AB
25 CONTINUE
RETURN
END
SUBROUTINE ASSYP (A, S1, S2, S3, SC, I, M, J, N, NCP)

PURPOSE: To assemble (add) the plate element stiffness or mass matrices (S1, S2, S3, SC) in the appropriate location in the system free-free stiffness or mass matrix (A).

SUBPROGRAMES REQUIRED: LOC

VARIABLES: A - System free-free stiffness or mass matrices
S1, S2, S3, SC - Partitioned element stiffness or mass matrix (see Subroutines PLTSTF and PLTMAS)
I - Index for bay number in x-direction
M - Number of grid points in x-direction
J - Index for bay number in y-direction
N - Number of grid points in y-direction
NCP - Number of coordinates per grid point

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000270

REFERENCES: None
BEGIN

COMPUTE INITIAL PARAMETERS

BEGIN COORDINATE COUNT AT GRID POINT

COMPUTE ELEMENT LOCATION IN ARRAYS $S_1, S_2, S_3$

COMPUTE ELEMENT LOCATION IN SUPERMATRIX, $A$

IS ROW COUNT EQL. TO OR GTR. THAN COL. COUNT?

$A(NKL) = A(NKL) + S_1(KL)$

$A(IKL) = A(IKL) + S_3(KL)$

$A(IKS) = A(IKS) + S_2(KLG)$

HAVE ALL COORDINATES BEEN CONSIDERED?

FLOW CHART: SUBROUTINE ASSYP ($A, S_1, S_2, S_3, SC, I, M, J, N, NCP$)
Appendix C

COMPUTE COLUMN LOCATION OF GEN. COORDINATE OF PANEL BAY, ICL

BEGIN ROW COUNT FOR GEN. COORDINATE

YES

K > 4
ICR = ICN + K - 1

NO

K > 8
ICR = ICK + NCP + K - 5

YES

K > 12
ICR = ICS + K - 9

NO

K > 16
ICR = ICL

YES

ICR = ICS + NCP + K - 13

COMPUTE SUBSCRIPT, ICC, IN SUPER MATRIX, A

A(ICC) = A(ICC) + SC(K)

YES

IS ROW COUNT COMPLETE?

NO

RETURN

FLOW CHART: SUBROUTINE ASSYP (A, S1, S2, S3, SC, I, M, J, N, NCP)
SUBROUTINE ASSYP(A, S1, S2, S3, SC, I, M, J, N, NCP)

DIMENSION A(2), S1(2), S2(2), S3(2), SC(2)
NCP=M*N+(M-1)*(N-1)
NL=2*NCP
NG=M*(J-1)+1
NQAY=(M-1)*(J-1)+I
ICN=NCP*(NG+1)+1
ICS=ICN+NCP*N
DO 20 K=1, NLM
DO 20 L=1, NLM
CALL LOC(K, L, KLS, NLM, 1)
CALL LOC(K, L, KLG, NLM, 0)
INK=ICN+K-1
INL=ICN+L-1
CALL LOC(INK, INL, NKL, NCO, 1)
IS=ICS+K-1
ISL=ICS+L-1
CALL LOC(ISK, ISL, IKL, NCO, 1)
CALL LOC(ISK, ISL, IKL, NCO, 1)
IF(K-L) 15, 10, 10
10 A(NKL)=A(NKL)+S1(KLS)
A(IKL)=A(IKL)+S3(KLS)
15 A(IKS)=A(IKS)+S2(KLG)
20 CONTINUE
ICL=NCP*M*N+NGAY
DO 70 K=1, 17
IF(K=4) 25, 25, 30
25 ICR=ICN+K-1
GO TO 65
30 IF(K=8) 35, 35, 40
35 ICR=ICN+NCP+K-5
GO TO 65
40 IF(K=12) 45, 45, 50
45 ICR=ICS+K-9
GO TO 65
50 IF(K=16) 55, 55, 60
55 ICR=ICS+NCP+K-13
GO TO 65
60 ICR=ICL
65 CALL LOC(ICR, ICL, ICR, NCO, 1)
A(ICC)=A(ICC)+SC(K)
70 CONTINUE
RETURN
END
SUBROUTINE RIB (I, IØP, D, S1, S2, S3)

PURPOSE: To compute the stiffness and consistent mass matrices for a finite element representation of a thin-walled open-section beam.

SUBPROGRAMS REQUIRED: Zero

VARIABLES:
- I - Index denoting rib number for constants in common data block with PLTVIB (see Figure 3)
- IØP - IØP = 1, stiffness matrix is computed
  IØP = 2, consistent mass matrix is computed
- D - Length of beam element
- S1, S2, S3 - Partitioned stiffness on mass matrix (see Flow Chart)

RESTRICTIONS: D ≠ 0

ACCURACY: See Reference 1, p. 8

SIZE: 001175

REFERENCES: Reference 1, pp. 5 - 11
Appendix C

BEGIN

INITIALIZE ARRAYS
S1, S2, S3
ZERO

YES

1 < 3

NO

RIB PARALLEL TO X-AXIS
SET AX = 1.0

RIB PARALLEL TO Y-AXIS
SET AX = 0.0

AY = 1.0 - AX

COMPUTE STIFF. PARAMETERS

FILL ARRAYS
S1(I) = K11
S2(I) = K12
S3(I) = K22
SEE APPENDIX A

RETURN

COMPUTE MASS. PARAMETERS

FILL ARRAYS
S1(I) = M11
S2(I) = M12
S3(I) = M22
SEE APPENDIX A

RETURN

FLOW CHART: SUBROUTINE RIB (I, IOP, D, S1, S2, S3)
SUBROUTINE RIB(I, IO, D, S1, S2, S3)
DIMENSION ER(4), GR(4), RH0(4), SR2(4), C2(4), SR3(4), C3(4),
S1(2), S2(2), S3(2)
COMMON ER, GR, RH0, SR2, C2, SR3, C3,
S1, A22, A23, A33, SJ, RE2, RE3, GM
CALL ZER0(S1, 36)
CALL ZER0(S2, 64)
CALL ZER0(S3, 36)
IF (I = 3) GO TO 5, 10, 10

5

AX = 0.0
GO TO 15

10

AX = 0.0

15

AY = 1.0 - AX
D2 = D * D

D3 = D * D * D
IF (IOP = 1) 20, 20, 25

20

B22 = ER(I) * A22(I) / D3
B23 = ER(I) * A23(I) / D3
B33 = ER(I) * A33(I) / D3
R2 = ER(I) * RE2(I) / D3
R3 = ER(I) * RE3(I) / D3

R2 = SR2(I) * B22 - SR3(I) * B23 - R2
RY = SR2(I) * B22 - SR3(I) * B23 + R2
G1 = ER(I) * GM(I) / D3 + GR(I) * SJ(I) / (1000 * D)
G2 = ER(I) * GM(I) / D3 * GR(I) * SJ(I) / 60.
G3 = ER(I) * GM(I) / D3 * GR(I) * SJ(I) / 30.
T1 = G1 + SR3(I) * SR3(I) * B32 - 2 * SR2(I) * SR3(I) * B23
1 + SR2(I) * SR2(I) * B22 - 2 * (SR3(I) * R3 - SR2(I) * R2)
T2 = G2 - (SR3(I) * R3 - SR2(I) * R2) * D
T1 = G1 + SR3(I) * SR3(I) * B32 - 2 * SR2(I) * SR3(I) * B23
1 + SR2(I) * SR2(I) * B22 + 2 * (SR3(I) * R3 - SR2(I) * R2) * D
T2 = G2 + (SR3(I) * R3 - SR2(I) * R2) * D

S1(1) = 12 * B22
S1(2) = 6 * (AY * B22 * D - 2 * AX * RY)
S1(3) = 4 * (AY * B22 * D2 + 3 * AX * T1X)
S1(4) = 6 * (2 * AX * RX = AX * B22 * D)
S1(5) = 6 * (AY * RX * D + AX * RY * D)
S1(6) = 4 * (3 * AX * T1Y + AX * B22 * D2)
S1(7) = 6 * (AY = AX) * R2 * D
S1(8) = 2 * (2 * AX * R2 * D2 + 3 * AX * T2X)
S1(9) = -2 * (3 * AX * T2X - 2 * AX * R2 * D2)
S1(10) = 4 * G3
S1(11) = -S1(1)
S1(2) = -S1(2)
S1(3) = -S1(4)
S1(4) = -S1(7)
S1(5) = 6 * (AY * B22 * D2 + 2 * AX * RY)
S1(6) = 2 * (AY * B22 * D2 - 6 * AX * T1X)
S1(7) = -6 * (AX * RX * D = AX * RX * D)
S1(8) = 2 * (AY * R2 * D2 - 3 * AX * T2X)
S1(9) = -6 * (2 * AX * RX + AX * B22 * D)
S1(10) = -6 * (AY * RX * D = AX * RY * D)
S1(11) = 2 * (AX * B22 * D2 - 6 * AX * T1Y)
S1(12) = 2 * (AX * R2 * D2 + 3 * AX * T2Y)
S1(13) = S1(17)
S1(14) = 2 * (AY * R2 * D2 + 3 * AX * T2X)

SUBPROGRAM RIB: CARD IMAGE LISTING 1/2
Appendix C

S2(15) = -2.*(3.*AY*T2Y-AX*R2*D2)
S2(16) = 2.*G4
S3(1) = S1(1)
S3(2) = -6.*((AY*B22+D+2.*AX*RY)
S3(3) = S1(3)
S3(4) = 6.*((2.*AY*RX+AX*B22*D)
S3(5) = -S1(5)
S3(6) = S1(6)
S3(7) = -S1(7)
S3(8) = 2.*(2.*AY*R2*D2-3.*AX*T2X)
S3(9) = 2.*(3.*AY*T2Y+2.*AX*R2*D2)
S3(10) = 4.*G3

RETURN

25

RM = RHO(I)*AR(I)*D/386
E2 = C2(I)-SR2(I)
E3 = C3(I)-SR3(I)
R = (E2*E2+E3*E3)/D2
Rp = (A22(I)+A33(I))/(AR(I)*D2)
P1 = 13./35.0
P2 = 11./210.
P3 = 1./105.
P4 = 9./70.
P5 = 13./420.
P6 = 1./140.

S1(1) = P1*RM
S1(2) = (P1*AX*E2+P2*AY*D)*RM
S1(3) = (P1*AX*(R+RP)+P3*AY)*RM*D2
S1(4) = (P2*AX*D+P1*AY*E2)*RM
S1(5) = -P2*E2*RM*D
S1(6) = (P3*AX+P1*AY*(R+RP))*RM*D2
S1(7) = P2*AX*RM*D3*RP
S1(8) = P2*AY*RM*D3*RP
S1(9) = P3*RM*D3*RP
S1(10) = P2*RM*D3*RP
S2(1) = P4*RM
S2(2) = (P4*AX*E2+P5*AY*D)*RM
S2(3) = -P5*AX*0+P4*AY*E2)*RM
S2(5) = (P4*AX*E2-P5*AY*D)*RM
S2(6) = (P4*AX*(R+RP)-P6*AY)*RM*D2
S2(7) = -P5*(AX-AY)*E2*RM*D
S2(8) = P5*AX*RM*D3*RP
S2(9) = (P5*AX*D-P4*AY*E2)*RM
S2(10) = S2(7)
S2(11) = -(P6*AX-P4*AY*(R+RP))*RM*D2
S2(12) = -P5*AY*RM*D3*RP
S2(14) = -P5*AX*RM*D3*RP
S2(15) = P5*AY*RM*D3*RP
S2(16) = -P6*RM*D*D3*RP
S3(1) = S1(1)
S3(2) = (P1*AX*E2-P2*AY*D)*RM
S3(3) = S1(3)
S3(4) = (P2*AX*D-P1*AY*E2)*RM
S3(5) = -S1(5)
S3(6) = S1(6)
S3(8) = -S1(8)
S3(9) = -S1(9)
S3(10) = S1(10)
RETURN

END
SUBROUTINE ASSYR (A, S1, S2, S3, I, M, J, N, NCP, AX)

PURPOSE: To assemble (add) the rib element stiffness or mass matrices (S1, S2, S3) in the appropriate location in the system free-free stiffness or mass matrix (A).

SUBPROGRAMS REQUIRED: LOC

VARIABLES: A - System free-free stiffness on mass matrices
          S1, S2, S3 - Partitioned element stiffness or mass matrix (see Subroutine Rib)
          I - Index for bay number in x-direction
          M - Number of grid points in x-direction
          J - Index for bay number in y-direction
          N - Number of grid points in y-direction
          NCP - Number of coordinates per grid point
          AX - Logic number: AX = 1.0 for ribs parallel to x-axis; AX = 0.0 for ribs parallel to y-axis

RESTRICTIONS: M ≤ 4, N ≤ 4

ACCURACY: Not Applicable

SIZE: 0002078

REFERENCES: None
begin

compute logic no. ay, size of supermatrix, a, and coordinate points of the rib element, icn, ics

begin coordinate count

compute element index for arrays s1, s2, and s3 loc

compute element location in supermatrix, a loc

is row count eql. or gtr. than col. count

yes

no

begin coordinate count

a(nkl) = a(nkl) + s1(kls)
a(ikl) = a(ikl) + s3(kls)
a(iks) = a(iks) + s2(klg)

have all coordinates been considered?

yes

no

return

flow chart: subroutine assyr (a, s1, s2, s3, i, m, j, n, ncp, ax)
SUBROUTINE ASSYR(A, S1, S2, S3, I, M, J, N, NC, P, AX)

DIMENSION A(2), S1(2), S2(2), S3(2)

\[ AY = 1 - AX \]

\[ NC = NC * M * N + (M - 1) * (N - 1) \]

\[ NG = M * (J - 1) + 1 \]

\[ IC = IC + \text{IFIX}(AX) * NC + \text{IFIX}(AY) * NC * M \]

\[
\begin{align*}
\text{DO} & \ 20 \ K = 1, NC \\
\text{DO} & \ 20 \ L = 1, NC \\
& \text{CALL LOC}(K, L, KLS, NC, 1) \\
& \text{CALL LOC}(K, L, KLG, NC, 0) \\
& \text{INK} = IC + K - 1 \\
& \text{INL} = IC + L - 1 \\
& \text{CALL LOC}(INK, INL, NKL, NC, 1) \\
& \text{IS} = IC + S + L - 1 \\
& \text{CALL LOC}(IS, ISL, IKL, NC, 1) \\
& \text{CALL LOC}(INK, ISL, IKS, NC, 1) \\
& \text{IF}(K - L) 15: 10: 10 \\
& 10 \ A(NKL) = A(NKL) + S1(KLS) \\
& 15 \ A(IKS) = A(IKL) + S2(KLG) \\
& 20 \ \text{CONTINUE} \\
& \text{RETURN} \\
& \text{END}
\end{align*}
\]
SUBROUTINE NONDIM (A,M,N,TK,TL)

PURPOSE: To nondimensionalize the stiffness and mass matrices of the stiffened panel structure.

VARIABLES:

A - Stiffness or mass matrix
M - Number of grid points in the x-direction
N - Number of grid points in the y-direction
TK - Nondimensionalizing parameter for force (stiffness matrix) on mass (mass matrix). In each case the parameter is calculated as the average value of the stiffness or mass of the direct twist terms. See Program PLTVIB statement numbers 270 to 290.
TL - Nondimensionalizing parameter for length. Taken as the diagonal length of bay 5 (see Figure 3) of the structure.

RESTRICTIONS: TK ≠ 0, TL ≠ 0

ACCURACY: Not Applicable

SIZE: 000444

REFERENCES: None
Appendix C

BEGIN

COMPUTE INITIAL PARAMETERS

BEGIN GRID POINT COUNT
IC = NCP, NCI, NCP

BEGIN COORDINATE COUNT
FOR EACH GRID POINT
COMPUTE ROW AND COLUMN INDICES: IROW, ICOL
COMPUTE LOCATION IN SUBMATRIX: IJ

COMPUTE SUBSCRIPT, IR, OF
ELEMENT IN SUPERMATRIX, A
LOC

COMPUTE NONDIMENSIONALIZING
PARAMETER, CL, AND MULTIPLY
A(IR) BY CL

HAVE ALL
COORDINATES BEEN
CONSIDERED AT
GRID POINT?

YES

HAVE ALL
GRID POINTS BEEN
CONSIDERED

YES

NO

FLOW CHART: SUBROUTINE NONDIM (A,M,N,TK,TL)

135
Appendix C

FLOW CHART: SUBROUTINE NONDIM \((A, M, N, TK, TL)\)
BEGIN COORDINATE COUNT FOR GEN. COORDINATES

COMPUTE COLUMN LOCATION OF COUPLING TERMS, ICOL

BEGIN GRID POINT COUNT FOR COUPLING TERMS, L

COMPUTE ROW LOCATION OF COUPLING TERM FOR EACH COORDINATE

COMPUTE LOCATION OF ELEMENT IN SUPERMATRIX, A IRC

COMPUTE NONDIMENSIONALIZING PARAMETER, CL, AND MULTIPLY A(IRC) BY CL

HAVE ALL COORDINATES BEEN CONSIDERED?

HAVE ALL GRID POINTS BEEN CONSIDERED?

NONDIMENSIONALIZE GENERALIZED COORDINATES

RETURN

FLOW CHART: SUBROUTINE NONDIM (A, M, N, TK, TL)
SUBROUTINE NONDIM(A,M,N,TK,TL)
DIMENSION A(2)
NCP=4
NCI=NCP*M*N
NCO=NCI+(M-1)*(N-1)
NL=M*NCP*(M*N-M-2)+1
NBAND=NCP*(M+1)
MBAY=M-1
NBAY=NCP
DO 100 IC=NCP,NCI,NCP
   I1=IC+NCP+1
   DO 35 I=1,NCP
      IROW=I1+I-1
      DO 35 J=1,NCP
         ICOL=I1+J-1
         IJ=I+J*(J-1)/2
         CALL LOC(IROW,ICOL,IR,NCO,1)
      5 C.I=TL*TL/TK
      GO TO 30
10 C.I=TL/TK
      GO TO 30
15 C.I=1.0/TK
      GO TO 30
20 C.I=1.0/(TL*TK)
      GO TO 30
25 C.I=1.0/(TL*TL*TK)
30 A(IR)=C.I*A(IR)
35 CONTINUE
   IF(IC=NCI) GO TO 40
40 IC=IC+1
   IF(IC1=NL) GO TO 50
50 NBAND=NBAND-NCP+1
55 DO 95 JC=IC1,NU,NCP
   IF(JC=NCI) GO TO 55
95 DO 90 J=1,NCP
      ICOL=JC+J-1
      IROW=I1+I-1
      CALL LOC(IROW,ICOL,IR,NCO,1)
5 IJ=I+NCP*(J-1)
   10 C.I=TL*TL/TK
   GO TO 85
15 C.I=TL/TK
   GO TO 85
20 C.I=1.0/TK
   GO TO 85
25 C.I=1.0/(TL*TK)
   GO TO 85
30 C.I=1.0/(TL*TL*TK)
35 A(IR)=C.I*A(IR)
40 CONTINUE
50 CONTINUE
95 CONTINUE
100 CONTINUE
DO 155 J=1,NBAY
DO 155 I=1,MBAY
   IBAY=I+MBAY*(J-1)
   ICOL=NCI+IBAY
   ICS=(ICOL*ICOL-ICOL)/2
   IC=NCP*IBAY+NCP*(J-1)
   DO 150 L=1,4
      GO TO (105,110,115,120)*L
  105 IC'C=IC
      GO TO 125
  110 IC'C=IC+NCP
      GO TO 125
  115 IC'C=IC+NCP*M
      GO TO 125
  120 IC'C=IC+NCP*(M+1)
   DO 150 K=1,NCP
      IRR=IC'C-NCP+K
      IRC=IRR+ICS
      GO TO (130,135,135,140)*K
  130 CL=TL*TL/TK
      GO TO 145
  135 CL=TL/TK
      GO TO 145
  140 CL=1./TK
  145 A(IRC)=CL*A(IRC)
  150 CONTINUE
  155 CONTINUE
   CL=TL*TL/TK
   NS=NCI+1
   DO 160 I=NS,NCO
      II=I*(I+1)/2
      A(II)=CL*A(II)
  160 CONTINUE
   RETURN
END

SUBPROGRAM NONDIM: CARD IMAGE LISTING 2/2
SUBROUTINE ZERO (A, N)

PURPOSE: To set the first N elements of a single subscripted array to zero.

SUBPROGRAMS REQUIRED: None

VARIABLES: A - Array to be initialized
           N - Upper limit for elements of A set to zero

RESTRICTIONS: N must be equal to or less than the dimensioned size of A in the calling program.

ACCURACY: Not Applicable

SIZE: 000021

REFERENCES: None

SUBROUTINE FILL (A, B, N, MS)

PURPOSE: To fill array A with elements of array B

SUBPROGRAMS REQUIRED: LOC

VARIABLES: A - Single subscripted array
           B - Single subscripted array (symmetric storage mode: LOC)
           N - Number of rows or columns in A or B
           MS - Logic number: MS = 0 subroutine is bypassed; MS = 0, A is a general matrix (NXN) and B is a symmetric matrix; MS = 1, A and B are both symmetric matrices

RESTRICTIONS: None

ACCURACY: Not Applicable

SIZE: 000076

REFERENCES: See Subroutine LOC
BEGIN

YES

RETURN

NO

MS < 0

YES

MS = 0

NO

COMPUTE SUBSCRIPT FOR SYMMETRIC ARRAY B: IJS

LOC

COMPUTE SUBSCRIPT FOR GENERAL ARRAY A: IJG

LOC

FILL ARRAY A WITH ELEMENTS OF ARRAY B

FLOW CHART: SUBROUTINE FILL (A, B, N, MS)
SUBROUTINE ZERO(A,N)
DIMENSION A(2)
DO 5 I=1,N
A(I)=0.0
5 CONTINUE
RETURN
END

SUBPROGRAM ZERO: CARD IMAGE LISTING

SUBROUTINE FILL(A,B,N,MS)
DIMENSION A(2),B(2)
IF(MS) 25,5,15
5 DO 10 I=1,N
DO 10 J=1,N
CALL LOC(I,J,IJS,N,1)
CALL LOC(I,J,IJG,N,0)
A(IJG)=B(IJS)
10 CONTINUE
RETURN
15 NUP=N*(N+1)/2
DO 20 I=1,NUP
A(I)=B(I)
20 CONTINUE
25 RETURN
END

SUBPROGRAM FILL: CARD IMAGE LISTING
SUBROUTINE ORDER (A, NDEL, NCP, MI, NJ, NDL)

PURPOSE: To remove (set to zero) specified (constrained) coordinates in array A, reorder array A, and calculate the new size of array A.

SUBPROGRAMS REQUIRED: DELETE, LOC

VARIABLES: 
- A(I) - Stiffness or mass matrix of structural idealization
- NDEL(I) - Array of logic numbers: see PLTVIB
- NCP - Number of coordinates at each grid point
- MI - Number of grid points in x-direction
- NJ - Number of grid points in y-direction
- NDL - Number of coordinates removed by this subprogram
- NC(I) - Array of coordinate numbers for which NDEL(I) = 1

RESTRICTIONS: NC(I) must be dimensioned the same as NDEL(I) in program PLTVIB

ACCURACY: Not Applicable

SIZE: 000333

REFERENCES: None
Appendix C

BEGIN

INITIALIZE PARAMETERS
NDL, NGP, NCO

INITIALIZE ARRAY, NC(I)

BEGIN GRID
POINT COUNT, IC

BEGIN COORDINATE
COUNT AT GRID
POINT, J

YES
NO

NDEL(I1) = 1

INCREASE COUNT OF
DELETED COORDINATES
BY ONE: NDL = NDL + 1

PUT INDEX OF DELETED
COORDINATE IN ARRAY NC

YES
NO

J > NCP

YES
NO

IC > NGP

FLOW CHART: SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)
BEGIN DELETION OF COORDINATES

\(K = 1, NDL\)

\(M = \text{COORDINATE TO BE DELETED}\)

\(ML = \text{RESULTING SIZE OF ARRAY A}\)

\(N = ML + 1\)

SET ROW-COLUMN \(M\) OF SYMMETRIC ARRAY \(A\) TO ZERO

DELETE

BEGIN ORDER OF ELEMENTS OF SYMMETRIC ARRAY \(A\) FOR ROW-COLUMN LOCATIONS GREATER THAN \(M\)

BEGIN ROW COUNT, \(i\)

\(i = i + 1\)

BEGIN COLUMN COUNT, \(j\)

FLOW CHART: SUBROUTINE ORDER (\(A, NDEL, NCP, MI, NI, NDL\))
Appendix C

FLOW CHART:  SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)

B

COMPUTE INDEX, IJ, OF DELETED ELEMENT

LOC

YES

I = J

NO

J1 = J + 1

COMPUTE INDEX, IJ1, OF DIAGONAL ELEMENT

LOC

COMPUTE INDEX, IJ1, OF ELEMENT

LOC

A(IJ) = A(IJ1)

YES

J > N

NO

YES

I > ML

NO

BEGIN ORDER OF CONSTRAINT ARRAY, NC

YES

NC(I) > M

NO

NC(I) = NC(I) - 1

C

B1

B2

C1

FLOW CHART:  SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)
SHIFT OF ROW-COLUMNS IS COMPLETE.
SET TO ZERO ALL ELEMENTS IN
ROW-COLUMNS OF ARRAY A GREATER
THAN THOSE IN THE NEW SIZE OF
ARRAY A.

FLOW CHART: SUBROUTINE ORDER (A, NDEL, NCP, MI, NI, NDL)
SUBROUTINE ORDER(A, NDEL, NCP, MI, NI, NDL)
DIMENSION A(2), NDEL(2), NC(73)
NDL=0
NGP=MI*NI
NCO=NCP*NGP+(MI-1)*(NI-1)
DO 1 I=1,NCO
NC(I)=0
1 CONTINUE
DO 3 IC=1,NGP
I=NCP*(IC-1)
DO 3 J=1,NCP
IJ=I+J
IF(NDEL(IJ))=1,3,3,2
3 NDL=NDL+1
NC(NDL)=I
CONTINUE
31 DO 9 K=1,NDL
M=NC(K)
ML=NCO-K
N=ML+1
CALL DELETE(A,N,M)
DO 7 I=M,ML
I1=I+1
DO 7 J=1,N
CALL LOC(I,J,IJ,N,1)
IF(I-J)=5,4,5
7 CONTINUE
J1=J+1
CALL LOC(I1,J1,IJ1,N,1)
GO TO 6
5 CALL LOC(I1,J1,IJ1,N,1)
6 A(IJ)=A(IJ1)
7 CONTINUE
DO 9 I=1,NDL
IF(NC(I)-M)=9,9,8
8 NC(I)=NC(I)-1
9 CONTINUE
M=NCO-NDL+1
DO 10 K=M,NCO
CALL DELETE(A,NCO,K)
10 CONTINUE
RETURN
END

SUBROUTINE DELETE(A,N,J)
DIMENSION A(2)
DO 1 K=1,N
CALL LOC(K,J,KJ,N,1)
A(KJ)=0.0
1 CONTINUE
RETURN
END

SUBPROGRAMS ORDER AND DELETE: CARD IMAGE LISTINGS
INTRODUCTION

This appendix defines the input data parameters, input data format and output data format for the one-dimensional panel computer program and the two-dimensional panel computer program described in Appendix C. An example problem is included for each computer program listing typical input and output data formats.

ONE-DIMENSIONAL PANEL ARRAY

The one-dimensional panel geometry is illustrated in figure D-1. The structural idealization considers a fundamental mode across the width of the structure (y-direction) so that the finite element model considers only parameter variations along the length of the structure (strip analogy). The finite element model of the one-dimensional panel array then reduces to a simulation of a spring-supported beam. The elastic supports are modeled using the finite element representation of a thin-walled open-section beam as described in reference 1. The lumped parameter model of the elastic supports is given by equations 20a and 20b of reference 1. The definition of the geometric constants given in equations 20a and 20b of reference 1 are defined by figure D-2. The stiffener geometry for a stiffener parallel to the x-axis is presented in figure D-3 for completeness. The definition of the required input data is given below. The choice of structural idealization is best illustrated by an example problem.

ONE-DIMENSIONAL PANEL ARRAY: DEFINITION OF INPUT VARIABLES

The modal analysis of one-dimensional panel arrays is preformed using program BMPROP and the associated subprograms (see page 63). Definition of the required input variables is as follows:

NCASE   Number of data cases to be processed
NDATA   A four digit data case identification number
NBAY    The number of panel bays of the structure (not greater than 5)
Appendix D

NSUP The number of elastic supports

IOUT Data output option: IOUT = 0; print parameters NDATA, TK, TL, TM, frequencies and modal amplitudes at each grid point; IOUT > 0; print output for IOUT = 0 and the normalized modal displacement, shear, and bending moment distribution.

IBL Logic number for applying clamped constraints at the left-hand end of the structure: IBL = 0; left-hand end is free or elastically supported: IBL = 1 if the left-hand end of the structure is clamped (translation and slopes set to zero)

IBR Logic number for applying clamped constraints at the right-hand end of the structure (definition identical to IBL)

NINT Number of points interior to each element for which normalized displacement shear and bending moment distributions are to be calculated (equal to or less than 5)

BW Width b of the panel, inches, (see figure D-1)

PR Poisson's ratio for the cover sheet material

NEL(I) Number of elements in the Ith panel bay

EI(I) Bending rigidity of Ith panel bay (see equation 21, reference 1, p. 11), Ib.-in.2

WB(I) Weight per unit length of Ith panel bay (see equation 22, reference 1, p. 11), lb./in.

BL(I) Length of Ith panel bay (dimension a, figure D-1)

NCP(I) Translation coordinate number for locating Ith elastic support in structure NCP(I) will be an odd number

SL(I) Lumped spring constant, Kzz, for the Ith elastic support (see equation 20a, reference 1, p. 11)

SC(I) Lumped spring constant, Kz00, for the Ith elastic support (see equation 20a, reference 1, p. 11)

SR(I) Lumped spring constant, K000, for the Ith elastic support (see equation 20a, reference 1, p. 11)

RL(I) Lumped mass constant, Izz, for the Ith elastic support (see equation 20b, reference 1, p. 11)
Appendix D

RC(I) Lumped mass constant, $l_{20}$, for the $I^{th}$ elastic support (see equation 20b, reference 1, p. 11)

RR(I) Lumped mass constant, $l_{90}$, for the $I^{th}$ elastic support (see equation 20b, reference 1, p. 11)

Note: To add a lumped mass at a coordinate, input an elastic support with zero stiffness at that coordinate (i.e., SL(I) = SC(I) = SR(I) = 0 at NCP(I))

The input data format is as follows:

CARD 0 (ONE CARD PER DATA SET = NCASE DATA CASES)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(15)</td>
<td>NCASE</td>
</tr>
</tbody>
</table>

DATA CASE INPUT FORMAT

CARD 1 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(15)</td>
<td>NDATA</td>
</tr>
<tr>
<td>6(13)</td>
<td>NBAY</td>
</tr>
<tr>
<td>9(13)</td>
<td>NSUP</td>
</tr>
<tr>
<td>12(13)</td>
<td>IOUT</td>
</tr>
<tr>
<td>16(13)</td>
<td>IBL</td>
</tr>
<tr>
<td>18(13)</td>
<td>IBR</td>
</tr>
<tr>
<td>21(13)</td>
<td>NINT</td>
</tr>
</tbody>
</table>

CARD 2 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>4(E12.5)</td>
<td>BW</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>PR</td>
</tr>
</tbody>
</table>

CARDS 3 through 3+ NBAY (ONE CARD FOR EACH STRUCTURE BAY)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(13)</td>
<td>NEL(I)</td>
</tr>
<tr>
<td>4(E12.5)</td>
<td>EI(I)</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>WB(I)</td>
</tr>
<tr>
<td>28(E12.5)</td>
<td>BL(I)</td>
</tr>
</tbody>
</table>

CARDS 4 + NBAY through 4 + NBAY + 2 NSUP (TWO CARDS FOR EACH ELASTIC SUPPORT)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>1(13)</td>
<td>NCP(I)</td>
</tr>
<tr>
<td>5(E12.5)</td>
<td>SL(I)</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>SC(I)</td>
</tr>
<tr>
<td>28(E12.5)</td>
<td>SR(I)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>5(E12.5)</td>
<td>RL(I)</td>
</tr>
<tr>
<td>16(E12.5)</td>
<td>RC(I)</td>
</tr>
<tr>
<td>28(E12.5)</td>
<td>RR(I)</td>
</tr>
</tbody>
</table>
To illustrate a typical structural idealization consider a one-dimensional panel array consisting of three bays with two interior elastic supports and both ends clamped. Suppose that the span of each bay is 6.0 inches and that the width of the structure is 20.0 inches. The cover sheet is 0.032 in. and the material is 7075-T6 aluminum alloy. The stiffener is taken as a zee section as illustrated in figure 13, reference 1, and the stiffener orientation is taken such that both stiffeners face in the same direction. This data case corresponds to specimen SPI-2-1 for the three-bay configuration described in figure 15 of reference 1. Assuming that the stiffener attach point is directly below the vertical web and that the mass of the skin directly adjacent to the stiffener flange is considered to act with the translational inertia term, $I^*_zz$, for the lumped mass representation the stiffener data is

\[
K_{zz} = 630.02 \quad I^*_zz = 0.074299
\]

\[
K_{z\theta} = 14.271 \quad I^*_z\theta = 0.0
\]

\[
K_{\theta\theta} = 118.30 \quad I^*_\theta\theta = 0.0074605
\]

Since the cover sheet is uniform, the lumped data are

\[
EI(l) = 313.34 \quad WB(l) = 0.03232 \quad l = 1,2,3.
\]

Three* elements are used to model each bay.

The above structural idealization is illustrated in figure D-4. The input data format is illustrated in figure D-5. The output data format is illustrated in figure D-6. In figure D-6 the edited input data is printed, the eigenvalues and eigenvectors are printed, and the interpolated values of the displacement (W), slope (DW/DX), shear (V), and bending moment (M) are printed for the fifteen lower frequency modes (only the fundamental mode is illustrated). The sequence for listing the eigenvector is dimensionless displacement and rotation for each grid point across the structure (see figure D-4). The experimental values for frequency, mode shape, and bending moment distribution (strain) are given in Table II and figure 26 of reference 1.

*Experience has shown that (NBAY-1) elements for each bay insures satisfactory frequency convergence of the lower NBAY modes.
NINE-BAY TWO-DIMENSIONAL PANEL ARRAY

The two-dimensional panel array considered here is the nine-bay configuration illustrated in figure D-7. The structural idealization considers nine plate elements forming the cover sheet and orthogonal stiffeners. The plate elements are described in reference 1 and consider an interior fundamental clamped-clamped plate mode as a generalized coordinate. The stiffener elements are taken as thin-walled open-section beams as described in reference 1. The stiffener geometry is illustrated in figures D-2 and D-3. The element nomenclature is illustrated in figure 3. Definition of the input data is given below.

NINE-BAY TWO-DIMENSIONAL PANEL ARRAY: DEFINITION OF INPUT VARIABLES

The modal analysis of nine-bay two-dimensional panel arrays is performed using program PLTVIB and the associated subprograms (see page 103). Definition of the required input variables (see Subroutine RDNWRT (1)) is as follows:

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>NDATA</td>
<td>Number of data cases to be processed</td>
</tr>
<tr>
<td>NCASE</td>
<td>A four digit data case identification number</td>
</tr>
<tr>
<td>A(I)</td>
<td>Length of the I\textsuperscript{th} rib segment parallel to the x-axis (see figure D-7), inches</td>
</tr>
<tr>
<td>B(I)</td>
<td>Length of the I\textsuperscript{th} rib segment parallel to the y-axis (see figure D-7), inches</td>
</tr>
<tr>
<td>EP</td>
<td>Young's modulus of the cover sheet material, lbf./in.\textsuperscript{2}</td>
</tr>
<tr>
<td>HP</td>
<td>Thickness of the cover sheet material, inches</td>
</tr>
<tr>
<td>PR</td>
<td>Poisson's ratio of the cover sheet material</td>
</tr>
<tr>
<td>RHOP</td>
<td>Weight density of the cover sheet material, lbf./in.\textsuperscript{3}</td>
</tr>
<tr>
<td>ER(I)</td>
<td>Young's modulus for the I\textsuperscript{th} rib, lbf./in.\textsuperscript{2}</td>
</tr>
<tr>
<td>GR(I)</td>
<td>Shear modulus for the I\textsuperscript{th} rib, lbf./in.\textsuperscript{2}</td>
</tr>
<tr>
<td>RHO(I)</td>
<td>Weight density for the I\textsuperscript{th} rib, lbf./in.\textsuperscript{3}</td>
</tr>
<tr>
<td>SR2(I)</td>
<td>S\textsubscript{y} (I = 1, 2) and S\textsubscript{x} (I = 3, 4), inches*</td>
</tr>
<tr>
<td>C2(I)</td>
<td>C\textsubscript{y} (I = 1, 2) and C\textsubscript{x} (I = 3, 4), inches*</td>
</tr>
<tr>
<td>SR3(I)</td>
<td>S\textsubscript{z}', inches*</td>
</tr>
<tr>
<td>C3(I)</td>
<td>C\textsubscript{z}', inches*</td>
</tr>
</tbody>
</table>

*See figures D-2 and D-3
Appendix D

AR(I)  Cross sectional area of $I^{th}$ rib, in.$^2$
A22(I)  $I_{yy}$ ($I = 1, 2$) and $I_{xx}$ ($I = 3, 4$) of the $I^{th}$ rib, in.$^4$ (equation 5a, ref. 1)
A23(I)  $I_{yx}$ ($I = 1, 2$) and $I_{xz}$ ($I = 3, 4$) of the $I^{th}$ rib, in.$^4$ (equation 5a, ref. 1)
A33(I)  $I_{zz}$ of the $I^{th}$ rib, in.$^4$ (equation 5a, ref. 1)
SJ(I)  St. Venant's torsion constant, in.$^4$ (equation 5a, ref. 1)
RE2(I)  $R_{ey}$ ($I = 1, 2$) and $R_{ex}$ ($I = 3, 4$), in.$^5$** (equation 5b, ref. 1)
RE3(I)  $R_{ez}$ for the $I^{th}$ rib, in.$^5$** (equation 5b, ref. 1)
GM(I)  Warping constant for the $I^{th}$ rib, in.$^6$

The input data format is as follows:
CARD 0 (ONE CARD PER DATA SET)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
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</tbody>
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CARD 1 (ONE CARD PER DATA CASE)

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<tbody>
<tr>
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</tbody>
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CARD 2 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
<td>5(E12.5)</td>
<td>A(1)</td>
</tr>
<tr>
<td>17(E12.5)</td>
<td>A(2)</td>
</tr>
<tr>
<td>29(E12.5)</td>
<td>A(3)</td>
</tr>
</tbody>
</table>

CARD 3 (ONE CARD PER DATA CASE)

<table>
<thead>
<tr>
<th>COL (FORMAT)</th>
<th>NAME</th>
</tr>
</thead>
<tbody>
<tr>
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<td>B(1)</td>
</tr>
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<td>17(E12.5)</td>
<td>B(2)</td>
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<td>29(E12.5)</td>
<td>B(3)</td>
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CARD 4 (ONE CARD PER DATA CASE)

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<td>HP</td>
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<td>29(E12.5)</td>
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<td>RHOP</td>
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CARDS 5, 9, 13, 17 (ONE EACH PER DATA CASE)

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<tr>
<td>17(E12.5)</td>
<td>GR(I)</td>
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<td>29(E12.5)</td>
<td>RHO(I)</td>
</tr>
</tbody>
</table>

**See comment on page 6 of reference 1.
NINE-BAY TWO-DIMENSIONAL PANEL ARRAY: EXAMPLE

As an example consider a square nine-bay stiffened panel with identical stiffeners uniformly spaced in x- and y-directions. This example is selected to illustrate the nature of repeated roots and symmetry in the eigenvector (mode shape). Assume that each bay has dimensions \((A(l) \times B(l))\) of 10.0 in. \(\times\) 10.0 in., that the aluminum cover sheet is 0.032 in. thick, and that the stiffeners are described by the following data:

- \(ER(I) = 10.3 \times 10^6\) lbf./in.\(^2\)
- \(GR(I) = 3.9 \times 10^6\) lbf./in.\(^2\)
- \(RHO(I) = 0.101\) lbf./in.\(^3\)
- \(SR2(I) = 0.0\) in.
- \(C2(I) = 0.0\) in.
- \(SR3(I) = 0.27191\) in.
- \(C3(I) = 0.80525\) in.
- \(AR(I) = 0.120\) in.\(^2\)
- \(A22(I) = 0.018389\) in.
- \(A23(I) = 0.0\) in.
- \(A33(I) = 0.022298\) in.
- \(SJ(I) = 4.08 \times 10^5\) in.\(^4\)
- \(RE2(I) = 0.0\) in.
- \(RE3(I) = 0.0\) in.
- \(GM(I) = 2.4445 \times 10^{-3}\) in.\(^6\)
The stiffener cross-section shape and its attachment to the cover sheet is illustrated in figure D-8. Figure D-9 illustrates the input data format. Figure D-10 illustrates the output data format where the edited input data is printed and the eigenvalues and eigenvectors are printed. The sequence for printing the eigenvectors is illustrated in figure D-11. The mode shapes for the four lower frequency modes are given in figure D-12.

FIGURE D-1. ONE-DIMENSIONAL PANEL ARRAY
FIGURE D-2. CROSS-SECTION GEOMETRY FOR RIBS PARALLEL TO Y-AXIS

FIGURE D-3. CROSS-SECTION GEOMETRY FOR RIBS PARALLEL TO X-AXIS
Appendix D

a) Section through Centerline of Structure

b) Coordinates for Initial (unconstrained) Structural Idealization

c) Coordinates for Final (constrained) Structural Idealization

FIGURE D-4. STRUCTURAL IDEALIZATION: EXAMPLE PROBLEM THREE BAY ONE-DIMENSIONAL PANEL
FIGURE D-5. EXAMPLE PROBLEM: INPUT DATA FORMAT PROGRAM BMPROP.
### Appendix D

**FREE VIBRATION OF A ONE DIMENSIONAL PANEL ARRAY**

**DATA CASE 12**

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<th>3</th>
<th>NUMBER OF SUPPORTS</th>
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<td>0.32050E+00</td>
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<table>
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<tr>
<th>BAY NUMBER</th>
<th>ELEMENTS</th>
<th>BENDING RIGIDITY</th>
<th>WEIGHT PER UNIT AREA</th>
<th>LENGTH</th>
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<tbody>
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<td>0.32320E-01</td>
<td>0.60000E+01</td>
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<tr>
<td>2</td>
<td>3</td>
<td>0.31334E+03</td>
<td>0.32320E-01</td>
<td>0.60000E+01</td>
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<td>3</td>
<td>3</td>
<td>0.31334E+03</td>
<td>0.32320E-01</td>
<td>0.60000E+01</td>
</tr>
</tbody>
</table>

**SUPPORT NO. 1**

KZZ = 0.63002E+03  
KZTHETA = 0.14271E+03  
IZZ = 0.74299E-01  
INPUT COORDINATE = 7

**SUPPORT NO. 2**

KZZ = 0.63002E+03  
KZTHETA = 0.14271E+03  
IZZ = 0.74299E-01  
INPUT COORDINATE = 13

**FIGURE D-6. OUTPUT DATA FORMAT:** EDITION OUTPUT DATA, EXAMPLE PROBLEM
FREE VIBRATION OF A ONE-DIMENSIONAL PANEL ARRAY

DATA CASE 12

FIGURE D-6. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

FREQUENCY: 0.22146E+04 Hz

MODE SHAPE
-0.59286E-02-0.81602E-01 0.64859E-02-0.86498E-01 0.12723E-01 0.65049E-01 0.38799E-01 0.69348E+00
-0.39015E-01 0.69162E+00-0.12570E-01 0.62628E-01-0.65202E-02-0.89272E-01 0.60839E-02-0.83510E-01

FREQUENCY: 0.21841E+04 Hz

MODE SHAPE
-0.17806E-01-0.24433E+00 0.14224E-01-0.27746E+00 0.51926E-02-0.27348E-01 0.32002E-02 0.38369E-01
-0.26304E-03 0.50487E-01 0.19794E-01 0.85765E-01 0.34796E-01 0.69230E+00-0.44287E-01 0.60669E+00

FREQUENCY: 0.21831E+04 Hz

MODE SHAPE
-0.44093E-01 0.60482E+00-0.34691E-01 0.68891E+00-0.96963E-02 0.89343E-01 0.31750E+02 0.10081E+00
-0.43906E-02 0.95477E-01 0.29662E-02 0.41345E-01 0.13246E-01 0.26822E+00-0.17115E-01 0.23438E+00

FREQUENCY: 0.16370E+04 Hz

MODE SHAPE
-0.16652E-02 0.24144E+00-0.33123E-01-0.14216E+00-0.12200E-01-0.32390E+00 0.48730E+01-1-0.55555E+00
-0.47718E-01 0.56086E+00-0.19684E-01 0.32229E+00-0.33770E-01 0.14464E+00-0.16789E+02-0.24787E+00

FREQUENCY: 0.15018E+04 Hz

MODE SHAPE
-0.14264E-01 0.49567E+00-0.52034E-01-0.38591E+00 0.12697E-01-0.26694E+00 0.25523E-01 0.36288E-01
-0.23380E-01 0.67884E-01-0.16057E-01-0.27151E+00 0.55155E-01-0.40966E+00 0.15161E-01 0.52807E+00

Appendix D
### Appendix D: Eigenvectors, Example Problem

**Frequency** = 0.14314E+04 Hz.

**Mode Shape**

<table>
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<tr>
<th>Eigenvector</th>
<th>Frequency</th>
<th>Description</th>
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<td>0.39897E-01</td>
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<tr>
<td>0.22984E-01</td>
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**Frequency** = 0.10779E+04 Hz.

**Mode Shape**

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<tr>
<td>0.92372E-01</td>
<td>0.57464E-01</td>
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**Frequency** = 0.91226E+03 Hz.

**Mode Shape**

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<th>Frequency</th>
<th>Description</th>
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<td>0.21049E-02</td>
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**Frequency** = 0.61498E+03 Hz.

**Mode Shape**

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<th>Frequency</th>
<th>Description</th>
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<tr>
<td>0.33638E+00</td>
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</tbody>
</table>

**Frequency** = 0.51252E+03 Hz.

**Mode Shape**

<table>
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<tr>
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<th>Frequency</th>
<th>Description</th>
</tr>
</thead>
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<td>0.24741E+00</td>
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<tr>
<td>0.81548E-01</td>
<td>0.36428E+00</td>
<td>0.37254E-01</td>
</tr>
</tbody>
</table>
FIGURE D-6. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

**FREQUENCY** = 0.40419E+03 Hz

**MODE SHAPE**

\[-0.19669E+00-0.47799E-03 0.99424E-01 0.32641E+00 0.22240E-01-0.44718E+00-0.20419E+00 0.24689E+00 \]

\[0.21339E+00 0.19202E+00-0.61853E-01-0.46601E+00-0.12521E+00 0.40674E+00 0.23926E+0 0.61541E-03 \]

**FREQUENCY** = 0.28569E+03 Hz

**MODE SHAPE**

\[-0.27949E+00-0.16821E+00-0.36683E-01 0.52010E+00 0.23223E+00-0.19090E+00-0.15459E+00-0.34219E+00 \]

\[-0.11761E+00 0.38588E+00 0.20996E+00 0.28396E-01-0.16393E-01-0.36728E+00-0.18785E+00 0.11089E+00 \]

**FREQUENCY** = 0.22294E+03 Hz

**MODE SHAPE**

\[-0.19303E+00-0.16827E+00-0.10257E+00 0.33362E+00 0.24598E+00 0.23351E+00 0.30065E+0 0.27188E+00 \]

\[-0.16491E+00-0.45049E+00-0.26182E+00 0.27734E+00 0.84665E-01 0.31378E+00 0.17286E+00 0.14884E+00 \]

**FREQUENCY** = 0.15081E+03 Hz

**MODE SHAPE**

\[0.70434E-02 0.87246E-02 0.10034E-01-0.38561E-02 0.33860E-02 0.46581E-02 0.97569E-02 0.19778E-01 \]

\[0.52189E-01 0.75095E-01 0.20502E+00 0.27794E+00 0.60333E+00 0.23110E+00 0.42329E+00 0.52442E+00 \]

**FREQUENCY** = 0.13356E+03 Hz

**MODE SHAPE**

\[0.37344E+00 0.48855E+00 0.59756E+00-0.11907E+00 0.26399E+00-0.34988E+00 0.14336E+00 0.18782E-02 \]

\[0.13263E+00-0.55597E-01 0.36349E-01-0.10653E+00-0.36281E-01-0.33011E-01 0.29893E-01 0.36190E-01 \]

**FREQUENCY** = 0.10932E+03 Hz

**MODE SHAPE**

\[0.11836E+00-0.15890E+00-0.18767E+00 0.59874E-01 0.21177E-01 0.34200E+00 0.43930E+0 0.33925E+00 \]

\[0.50686E+00-0.22071E+00 0.13715E+00-0.37636E+00-0.92173E-01-0.89548E-01-0.74344E-01 0.92762E-01 \]
Appendix D

FREQUENCY = 0.10932E+03 HZ.

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<th>DW/DX</th>
<th>V</th>
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<td>0.00000E+00</td>
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<table>
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</tr>
</tbody>
</table>

Figure D-6. Output Data Format: Normalized Mode, shape and stress resultants.
Figure D-7. Nine Bay Two-Dimensional Structure
FIGURE D-8. STIFFENER CROSS-SECTION SHAPE: EXAMPLE PROBLEM NINE-BAY TWO-DIMENSIONAL PANEL

$A = 0.120, \text{ in}^2$

$J = 0.0000408, \text{ in}^4$

$R_{ex} = 0.0, \text{ in}^5$

$R_{ez} = 0.0, \text{ in}^5$

$\Gamma_e = 0.0024445, \text{ in}^6^*$

*Pole taken at shear center

Shear Center

Attach Point

Skin

$t = 0.032, \text{ in.}$

$b = 1.000, \text{ in.}$

$h = 0.75, \text{ in.}$

$h_1 = 0.50, \text{ in.}$

$x = 0.533, \text{ in.}$

$e = 0.2719, \text{ in.}$

$A = 0.022299, \text{ in}^4$

$l_{xx} = 0.018389, \text{ in}^4$

$x = 0.533, \text{ in.}$

$e = 0.2719, \text{ in.}$
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</table>

FIGURE D-9. INPUT DATA FORMAT: EXAMPLE PROBLEM
Appendix D

DATA CASE 1000

FREE VIBRATION OF A NINE BAY ORTHOGONALLY STIFFENED PANEL

STRUCTURAL GEOMETRY

\[ A_1 = 0.10000\times10^2 \quad A_2 = 0.10000\times10^2 \quad A_3 = 0.10000\times10^2 \]

\[ B_1 = 0.10000\times10^2 \quad B_2 = 0.10000\times10^2 \quad B_3 = 0.10000\times10^2 \]

COVER SHEET DATA

- **Young's Modulus**: 0.103000E+08
- **Poisson's Ratio**: 0.320500E+00
- **Thickess**: 0.320000E-01
- **Weight/Volume**: 0.101000E+00
- **Bending Rigidity**: 0.313460E+02

STIFFENER DATA

**STIFFENERS PARALLEL TO X-AXIS**

- **STIFFENER NO. 1**
  - \( E = 0.103000\times10^8 \)
  - \( G = 0.390000\times10^7 \)
  - \( RHO = 0.101000\times10^0 \)
  - \( CY = 0.000000\times10^0 \)
  - \( SZ = 0.271910\times10^0 \)
  - \( CZ = 0.805250\times10^0 \)
  - \( A = 0.120000\times10^0 \)
  - \( IYY = 0.163890\times10^{-1} \)
  - \( IYZ = 0.000000\times10^0 \)
  - \( IZZ = 0.222980\times10^{-1} \)
  - \( J = 0.408000\times10^{-4} \)

**STIFFENERS PARALLEL TO X-AXIS**

- **STIFFENER NO. 2**
  - \( E = 0.103000\times10^8 \)
  - \( G = 0.390000\times10^7 \)
  - \( RHO = 0.101000\times10^0 \)
  - \( CY = 0.000000\times10^0 \)
  - \( SZ = 0.271910\times10^0 \)
  - \( CZ = 0.805250\times10^0 \)
  - \( A = 0.120000\times10^0 \)
  - \( IYY = 0.163890\times10^{-1} \)
  - \( IYZ = 0.000000\times10^0 \)
  - \( IZZ = 0.222980\times10^{-1} \)
  - \( J = 0.408000\times10^{-4} \)

**STIFFENERS PARALLEL TO Y-AXIS**

- **STIFFENER NO. 3**
  - \( E = 0.103000\times10^8 \)
  - \( G = 0.390000\times10^7 \)
  - \( RHO = 0.101000\times10^0 \)
  - \( CX = 0.000000\times10^0 \)
  - \( SZ = 0.271910\times10^0 \)
  - \( CZ = 0.805250\times10^0 \)
  - \( A = 0.120000\times10^0 \)
  - \( IX = 0.183890\times10^{-1} \)
  - \( IX^2 = 0.000000\times10^0 \)
  - \( IZZ = 0.222980\times10^{-1} \)
  - \( J = 0.408000\times10^{-4} \)

**STIFFENERS PARALLEL TO Y-AXIS**

- **STIFFENER NO. 4**
  - \( E = 0.103000\times10^8 \)
  - \( G = 0.390000\times10^7 \)
  - \( RHO = 0.101000\times10^0 \)
  - \( CX = 0.000000\times10^0 \)
  - \( SZ = 0.271910\times10^0 \)
  - \( CZ = 0.805250\times10^0 \)
  - \( A = 0.120000\times10^0 \)
  - \( IX = 0.183890\times10^{-1} \)
  - \( IX^2 = 0.000000\times10^0 \)
  - \( IZZ = 0.222980\times10^{-1} \)
  - \( J = 0.408000\times10^{-4} \)

**FIGURE D-10. OUTPUT DATA FORMAT: EDITED INPUT DATA, EXAMPLE PROBLEM**
Appendix D: Data Case 1000

NonDimensionalizing Constants

\[ \begin{align*}
&T = 0.11482E+06, \quad T_L = 0.14142E+02, \quad T_M = 0.1424E+02, \\
\end{align*} \]

Eigenvalue: \( 0.32763E+01 \)
Frequency: \( 0.2582E+04 \) Hz.

Eigenvalue: \( 0.40668E+00 \)
Frequency: \( 0.22116E+04 \) Hz.

Eigenvalue: \( 0.23187E+01 \)
Frequency: \( 0.2172E+04 \) Hz.

Eigenvalue: \( 0.89302E+00 \)
Frequency: \( 0.13484E+04 \) Hz.

Eigenvalue: \( 0.81502E+00 \)
Frequency: \( 0.12882E+04 \) Hz.

Figure D-10. Output data format: Eigenvalues and Eigenvectors, Example Problem.
### Appendix D

**Figure D-10. Output Data Format: Eigenvalues and Eigenvectors, Example Problem**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Eigenvalue</th>
<th>Eigenvector</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.12882E+00</td>
<td>0.81502E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
<tr>
<td>0.12373E+00</td>
<td>0.7519E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
<tr>
<td>0.12030E+00</td>
<td>0.37975E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
<tr>
<td>0.87932E+00</td>
<td>0.37975E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
<tr>
<td>0.76604E+00</td>
<td>0.2882E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
<tr>
<td>0.64767E+00</td>
<td>0.2066E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
</tbody>
</table>

**Table:**

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Eigenvalue</th>
<th>Eigenvector</th>
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</thead>
<tbody>
<tr>
<td>0.12882E+00</td>
<td>0.81502E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
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<td>0.2066E+00</td>
<td>0.1433E+00 -0.5507E-01 0.2139E-01</td>
</tr>
</tbody>
</table>

**Notes:**

- The table presents the output data format for eigenvalues and eigenvectors.
- The example problem demonstrates the usage of this format.
- The data includes frequency values and corresponding eigenvalues and eigenvectors.

---

**Figure D-10.** Output data format: eigenvalues and eigenvectors, example problem.
## Appendix D

### EIGENVALUES

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Eigenvalue</th>
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</thead>
<tbody>
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<td>0.06034E+00</td>
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<tr>
<td>0.97947E-01</td>
<td>0.06034E+00</td>
</tr>
<tr>
<td>0.61E+00</td>
<td>0.11086E+03</td>
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<tr>
<td>0.34193E-02</td>
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### EIGENVECTORS

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### FIGURE D-10

OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Eigenvector</th>
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</tr>
<tr>
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<td>0.06034E+00</td>
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</tbody>
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**Note:** The table above provides a sample of the output data format for eigenvalues and eigenvectors, illustrating the values for example problems.
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<th>FREQUENCY</th>
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<td>0.20068E+00</td>
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<tr>
<td>0.13705E-05</td>
<td>0.11086E+03, Hz</td>
</tr>
</tbody>
</table>

**Appendix D**

**FIGURE D-10. OUTPUT DATA FORMAT: EIGENVALUES AND EIGENVECTORS, EXAMPLE PROBLEM**
\{d_i\} = \begin{pmatrix} W_i/TL \\ \theta_x \\ \theta_y \\ \theta_{xy}*TL \end{pmatrix}

TL = Nondimensionalizing length

Eigenvectors listed in the sequence:

\{\{d_1\} , \{d_2\} , \{d_3\} , \{d_4\} , \{W_{01}/TL, W_{02}/TL, \ldots, W_{09}/TL\}\}

FIGURE D-11. EIGENVECTOR NOTATION: NINE-BAY TWO-DIMENSIONAL PANEL ARRAY
Mode: \( f = 106.2 \text{ Hz} \).

Mode: \( f = 108.62 \text{ Hz} \).

FIGURE D-12. MODE SHAPES: EXAMPLE PROBLEM
Appendix D

Mode: $f = 110.15$ Hz. (repeated root)

FIGURE D-12. MODE SHAPES: EXAMPLE PROBLEM
APPENDIX E

CHLADNI PATTERNS FOR STIFFENED PANEL ARRAYS

As described in the main text, photographs were taken of each mode excited. For the one-dimensional arrays, only the structure modes with fundamentals across the bay width are given except as indicated. Under each photograph appears the following notation:

\[ f = \frac{N}{M} : R : Q \]

where \( N \) is the experimental frequency for the mode.

\( M \) is the computed value (if applicable)

\( R \) is the speaker condition (see figure 15, reference 1)

\( Q \) is the number of unsupported bays (\( Q = 5 \) or \( Q = 3 \)).

Not all of the modes illustrated were predominant.

The modal patterns for the nine-bay specimens are also given. All of the predominant modes excited consisted of coupled fundamental modes for the individual bays. Higher modes are also illustrated. The notation indicating the experimental frequency, the computed frequency, and the speaker phase condition is similar to that described above.
Appendix E

f = 82/92: A:5

f = 119/121: A:5

f = 126/117: A:5

f = 106/11: A:5

f = 108/101: A:3

f = 234/-: A:5

f = 115/-: A:3

f = 127/151: B:3

CHLADNI PATTERNS SPECIMEN SPI-1
CHLADNI PATTERNS SPECIMEN SPI-2-1
CHLADNI PATTERNS SPECIMEN SPI-2-1D
Appendix E

f = 57/70: A: 5
f = 61/--: A: 5
f = 68/--: A: 5
f = 94/110: B: 5
f = 98/--: B: 5
f = 51/71: A: 3
f = 61/--: A: 3
f = 67/--: A: 3

CHLADNI PATTERNS SPECIMEN  SPI-2-2
$f = 55/\cdot: A:5$

$ f = 68/68:D:5$

$ f = 91/\cdot: A:5$

$ f = 96/102:B:5$

$ f = 102/\cdot: A:3$

$ f = 112/\cdot: A:3$

CHLADNI PATTERNS SPECIMEN SPI-2-2D
Appendix E

CHLADNI PATTERNS SPECIMEN  SPI-3-1
CHLADNI PATTERNS SPECIMEN SPI-3-2D
CHLADNI PATTERNS FOR MACHINED 9 BAY SPECIMEN
CHLADNI PATTERNS FOR MACHINED 9 BAY SPECIMENT
CHLADNI PATTERNS FOR 9 BAY SPECIMEN SPII-1
CHLADNI PATTERNS FOR 9 BAY SPECIMEN SPII-2
REFERENCES


