SHEAR FLOW AND NORMAL STRESS ANALYSIS OF MULTI-CELL SEMI-MONOCOQUE STRUCTURES BY HIGH SPEED COMPUTERS

By

DAVID G. BAHOS

Bachelor of Science

University of Oklahoma

Norman, Oklahoma

1954

Submitted to the Faculty of the Graduate School of
the Oklahoma State University
in partial fulfillment of the requirements
for the degree of
MASTER OF SCIENCE
August, 1960

SHEAR FLOW AND NORMAL STRESS ANALYSIS OF

MULTI-CELL SEMI-MONOCOQUE STRUCTURES

BY HIGH SPEED COMPUTERS

Roger L. Flanders
Thesis Adviser

Tom J. Parker

Robert MacVicar
Dean of the Graduate School

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

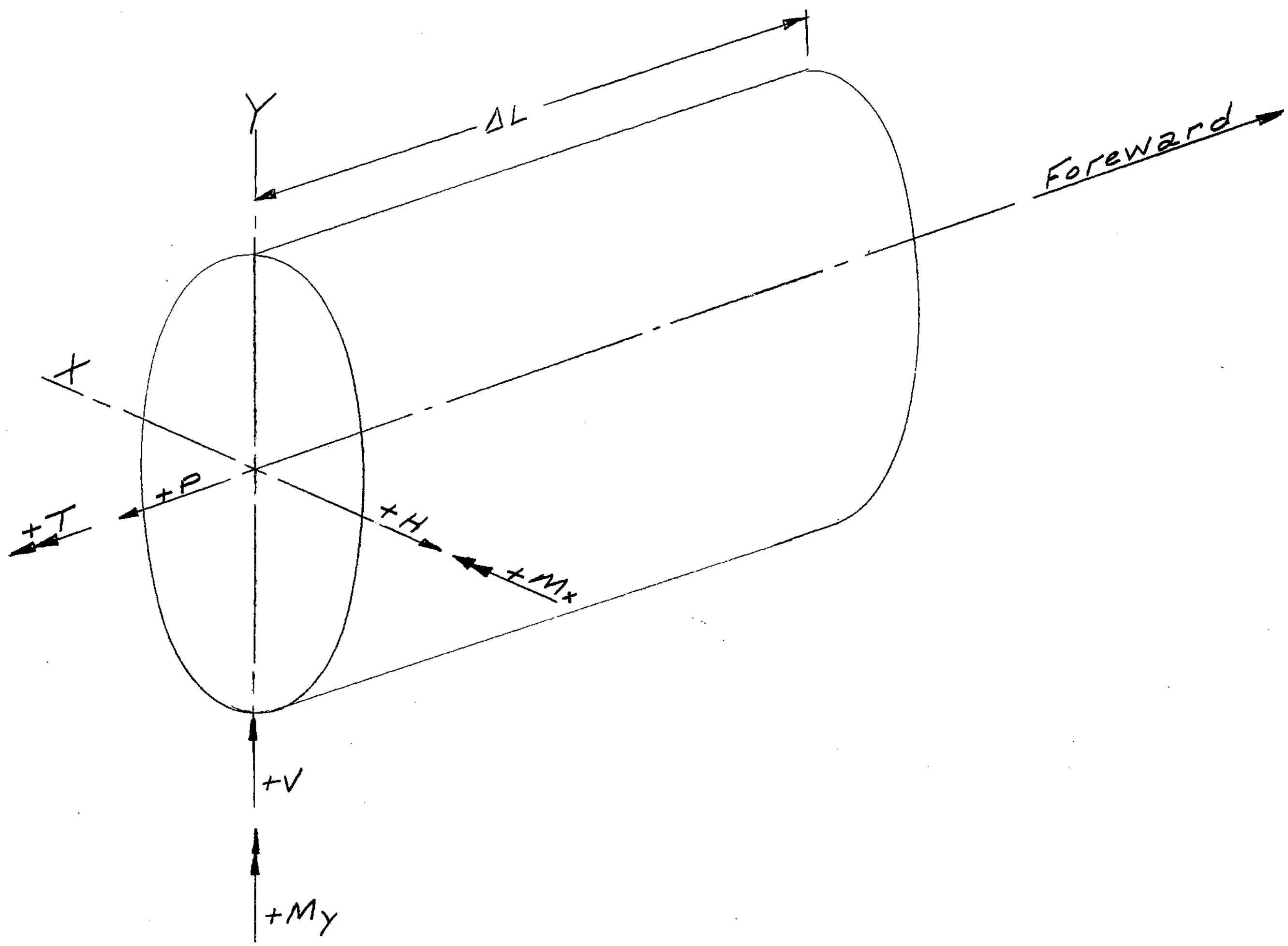


Figure 1

Sign Convention for Applied Loads

SIGN CONVENTION
(See Figure 1)

Linear dimensions and distances are positive when measured either to the right or upward from a point of reference. A section should be viewed from aft of its station number looking forward in order that its right and left sides may be seen in their proper relation.

Angular dimensions are positive when measured clockwise about a point of reference.

Shear loads are positive when they act either upwards or to the right on a section.

Torque loads are positive when they act counterclockwise on the section.

Axial loads are positive when they produce tension on a section.

Shear flows are positive when they act in a counterclockwise direction along the periphery of the section.

Normal stresses are positive when the stressed member is in tension.

Bending moments are positive when they produce compression in the top and right side of the section.

NOMENCLATURE

A_n = The total effective area of the $(n)^{th}$ element in the section

$$A_n = Al_n + Asc_n \text{ or } Ast_n$$

Ast_n = The area of skin in tension acting with the n^{th} stringer

$$Ast_n = .5 \left[t_n(ds_n) + t_{n-1}(ds_{n-1})\right]$$

Al_n = The cross sectional area of the longitudinal stringer in the $(n)^{th}$ element

Asc_n = The area of skin in compression acting with the n^{th} stringer

$$Asc_n = 15\ (t_n^2 + t^2_{(n-1)})$$

B = Normal stress effectivity factor

$\overline{B}$ = Shear flow effectivity factor

E = The modulus of elasticity (considered constant in this analysis)

G = The modulus of rigidity (considered constant in this analysis)

H = The total horizontal shear load on the section applied at the X reference axis

Ix = The moment of inertia of the section about its centroidal X axis

$$Ix = \sum (Ahy^2)$$

Iy = The moment of inertia of the section about its centroidal Y axis

$$Iy = \sum (Ahx^2)$$

Ixy = The product of inertia of the section about its centroidal X and Y axis

$$Ixy = \sum (Ahxhy)$$

K_1 = $\text{Sin } \theta = \dfrac{M\overline{y}Ix - M\overline{x}Ixy}{\sqrt{(M\overline{y}Ix - M\overline{x}Ixy)^2 + (M\overline{x}Iy - M\overline{y}Ixy)^2}}$

K_2 = $\text{Cos } \theta = \dfrac{M\overline{x}Iy - M\overline{y}Ixy}{\sqrt{(M\overline{y}Ix - M\overline{x}Ixy)^2 + (M\overline{x}Iy - M\overline{y}Ixy)^2}}$

Mx = The bending moment about the X axis

My = The bending moment about the Y axis

$M\overline{x}$ = The total bending moment about the X axis

$$M\overline{x} = Mx + P\overline{y}$$

$M\bar{y}$ = The total bending moment about the Y axis

$$M\bar{y} = My + P\bar{x}$$

N_1 = A normal stress coefficient

$$N_1 = \frac{-M\bar{x}Iy + M\bar{y}Ixy}{-Ixy^2 + IxIy}$$

N_2 = A normal stress coefficient

$$N_2 = \frac{-M\bar{y}Ix + M\bar{x}Ixy}{-Ixy^2 + IxIy}$$

N_3 = A normal stress coefficient

$$N_3 = \frac{P}{\sum(A)}$$

N = The final element number

P = The axial load on the section applied at the junction of the X and Y reference axes

Qx_n = The sum of the area products of the first through $(n)^{th}$ element about the centroidal X axis

$$Qx_n = \sum_1^n (Ahy)$$

Qy_n = The sum of the area products of the first through $(n)^{th}$ element about the centroidal Y axis

$$Qy_n = \sum_1^n (Ahx)$$

R^q = The ratio of the enclosed area of cell #1 to cell q

$$R^q = \frac{\sum' m}{\sum q_m}$$

R_n = The distance from the n^{th} element normal to the resultant neutral axis

$$R_n = -K_2 hy_n - K_1 hx_n$$

S_1 = A shear flow coefficient

$$S_1 = \frac{-HxIxy + VyIy}{-Ixy^2 + Ixy}$$

S_2 = A shear flow coefficient

$$S_2 = \frac{-VyIxy + HxIx}{-Ixy^2 + IxIy}$$

T = The total torque load acting on the section

T^q = The constant shear flow coefficient or torsional equilibrium factor for each cell

Tx = The torsional inertia of the section about its centroidal X axis

$$Tx = \sum (Qxm)$$

Ty = The torsional inertia of the section about its centroidal Y axis

$$Ty = \sum (Qym)$$

Tx^q = A tangential deflection term for the shear stresses for each cell

$$Tx^q = \sum^q (Qxms)$$

Ty^q = A tangential deflection term for the shear stresses for each cell

$$Ty^q = \sum^q (Qyms)$$

$\overline{Tx}^q$ = A collection term

$$\overline{Tx}^q = Tx^1 - R^q \, Tx^q$$

$\overline{Ty}^q$ = A collection term

$$\overline{Ty}^q = Ty^1 - R^q Ty^q$$

V = The total shear load acting on the section applied at the Y reference axis

X_n = The abscissa of the $(n)^{th}$ element in the section with respect to the reference Y axis

$\overline{X}$ = The abscissa of the centroid of the total effective area of section with respect to the reference Y axis

$$\overline{X} = \frac{\sum (AX)}{\sum (A)}$$

Y_n = The ordinate of the $(n)^{th}$ element in the section with respect to the reference X axis

$\overline{Y}$ = The ordinate of the centroid of the total effective area of the section with respect to the reference X axis

$$\overline{Y} = \frac{\Sigma(AY)}{\Sigma(A)}$$

θ = The angle between the centroidal and neutral axis

$$\theta = \text{Tan}^{-1} \frac{M\overline{y}Ix - M\overline{x}Ixy}{M\overline{x}Iy - M\overline{y}Ixy}$$

Σ = The sum of the quantity indicated for all elements in the section

$$\Sigma(\quad) = \sum_{n=1}^{N}(\quad)$$

Σ_n = The sum of the quantity indicated from the first through the $(n)^{th}$ elements in the section

$$\Sigma_n(\quad) = \sum_{n=1}^{n}(\quad)$$

Σ^q = The sum of the quantity indicated for all elements in the $(q)^{th}$ cell

$$\Sigma^q(\quad) = \sum_{n=1}^{N}(\quad)^q$$

NOMENCLATURE (SMALL LETTERS)

dx_n = The differential abscissa between the $(n)^{th}$ and $(n+1)^{th}$ elements in the section

$$dx_n = X_{n+1} - X_n$$

dy_n = The differential ordinate between the $(n)^{th}$ and $(n+1)^{th}$ elements in the section

$$dy_n = Y_{n+1} - Y_n$$

ds_n = The peripheral distance between the $(n)^{th}$ and $(n+1)^{th}$ elements in the section

$$ds_n = \sqrt{dx_n^2 + dy_n^2}$$

fN_n = The total normal stress at the $(n)^{th}$ element in the section

$$fN_n = N_1 hy_n + N_2 hx_n + N_3$$

fs_n = The total shear flow between the $(n)^{th}$ and $(n+1)^{th}$ elements in the section

$$fs_n = S_1 Qx_n + S_2 Qy_n + T^q$$

hx_n = The abscissa of the $(n)^{th}$ element in the section with respect to the centroidal Y axis

$$hx_n = X_n - \overline{X}$$

hy_n = The ordinate of the $(n)^{th}$ element in the section with respect to the centroidal X axis

$$hy = Y_n - \overline{Y}$$

m_n = Twice the swept area subtended by the periphery between the n^{th} and $(n+1)^{th}$ elements in the section

$$m_n = Y_n dx_n - X_n dy_n$$

ms_n = $\frac{ds_n}{Gt_n}$

n = The serial number of an element in the section. An element consists of a stringer plus the skin that acts with it. The numbers from #1 through n are assigned consecutively in a clockwise direction to all elements

t_n = The skin thickness of the $(n)^{th}$ element. The thickness given for the $(n)^{th}$ element is for the skin between the n^{th} and $(n+1)^{th}$ stringer

q = A superscript of primes equal in number to the cell number in which it will act. (For cell #1, q = 1. For cell #2, q = 2, etc.)

COMMENTS ON NOMENCLATURE

1. The preceding nomenclature may at first seem extremely bulky to the reader, however, it will be shown in the text of the thesis that in order to provide the computer a simplified set of equations, it will be necessary to group several individual terms into one general expression or coefficient. These general expressions may remain constant or vary for every element in the cross-section under a given loading condition.

2. It will be assumed in this thesis that the reader is familiar with the majority of the basic equations involved in the section analysis of a multi-cell semi-monocoque structure. Therefore, a complete derivation of the basic equations listed in the nomenclature will be omitted.

ASSUMPTIONS

The following elastic analysis assumptions will be observed throughout this thesis:

1. The material of the beam is homogeneous and obeys Hook's law.
2. The moduli of elasticity for tension and compression are equal.
3. All deformations are small and elastic.

4. The beam is initially straight and of constant cross-section.

5. Plane sections of the beam, originally plane, remain plane.

There is an additional assumption that the effective skin area which acts with a stringer in compression is limited to a width of 15 skin thicknesses on each side of the stringer.

INTRODUCTION

The design and analysis of multi-cell semi-monocoque structures has been a problem, found primarily in the aircraft industry, for a good many years. This type of structure consists of stressed skin and longitudinal stringers. A typical example from a structural design standpoint would be a fuselage or wing cross section. Several authors such as E. F. Bruhn (1) or D. J. Peery (2) have outlined in detail a procedure one could make use of if the problem was being set up in tabular form. This tabular form is ideal for a relatively simple structure with a few cases of load combinations, however, when the structure becomes complex with numerous loading cases a more efficient method becomes necessary.

The intent of the thesis will be to outline a fixed method of tabular procedure permitting the use of punched card automatic tabulating equipment to perform most of the routine and repetitive operations.

In the preparation of such a method or program I encountered many problems. Some were solved by trial and error methods, others were eliminated after consulting directly with computer personnel who were capable of pointing out the limitations and capabilities of the high speed computers.

CHAPTER I

STATEMENT OF PROBLEM

The section analysis of a multi-cell semi-monocoque structure normally requires a great deal of time and patience due to the tremendous volume of calculations necessary when solving for section properties and stresses. As stated in the introduction, it will be the intent of this thesis to present a method whereby the analyst is relieved of the routine and repetitive operations required in this type of an analysis. In order to accomplish this, the equations will be presented in matrix form to the high speed computer operator who will code the equations into the machine. Once this is accomplised, the only variable, to be supplied by the analyst, will be the geometry and applied loads.

In order to provide a guide to the step by step procedure used in a complete section analysis, the data required and the calculations to be made are outlined in detail on the following pages.

CHAPTER II

NORMAL STRESS COEFFICIENTS

The normal stress coefficients N_1, N_2, and N_3 are functions of the applied loads and section properties, therefore being constant for every element in the section under a given load condition. Using the nomenclature shown in Figure (2-1) a solution will be set up in matrix form to determine the coefficients.

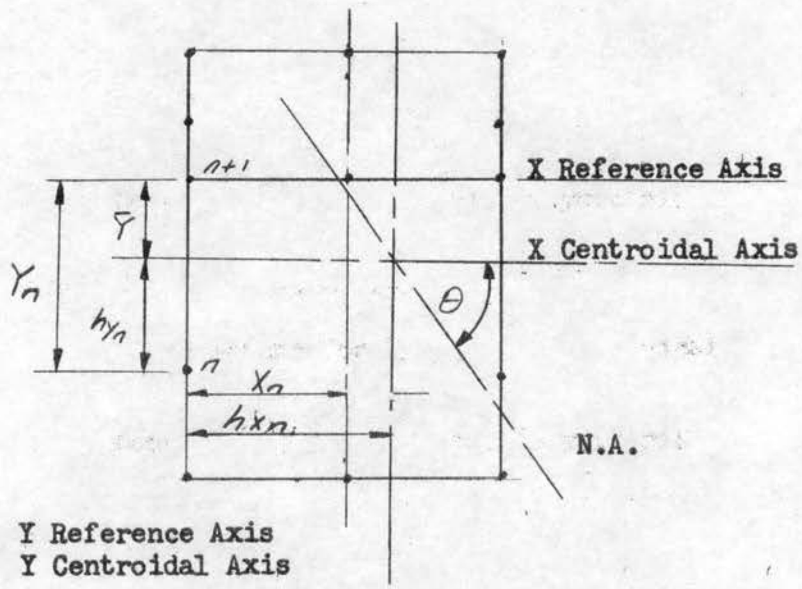


Figure (2-1)

Nomenclature for Typical Unsymmetrical
Cross Section in Bending

The normal stress for any element in the cross-section of Fig. (2-1) is:

$$f_b = \frac{-\bar{M}_x I_y + \bar{M}_y I_{xy}}{I_x I_y - (I_{xy})^2} h_y - \frac{\bar{M}_y I_x - \bar{M}_x I_{xy}}{I_x I_y - (I_{xy})^2} h_x \qquad (2\text{-}1)$$

Let $N_1 = \frac{-\bar{M}_x I_y + \bar{M}_y I_{xy}}{I_x I_y - (I_{xy})^2}$ and $N_2 = \frac{-\bar{M}_y I_x + \bar{M}_x I_{xy}}{I_x I_y - (I_{xy})^2}$

Then $fb = N_1hy + N_2hx$

Letting $P/A = N_3$

FN_n (total normal stress) $= N_1hy_n + N_2hx_n + N_3$ (2-2)

In order to solve for N_1 and N_2 simultaneously the following simplifications are performed:

$$N_1(Ix) = \frac{-M\bar{x}IyIx + M\bar{y}IxyIx}{IxIy - Ixy^2} \qquad N_2(Ixy) = \frac{M\bar{x}Ixy^2 - M\bar{y}IxyIx}{IxIy - Ixy^2}$$

Adding the two equations and simplifying we obtain

$$N_1(Ix) + N_2(Ixy) = - M\bar{x} \qquad (2\text{-}3)$$

In like manner if we were to multiply the equation for N_1 by Ixy, and the equation for N_2 by Iy, we would obtain the following expression

$$N_1(Ixy) + N_2(Iy) = - M\bar{y} \qquad (2\text{-}4)$$

The three normal stress coefficients N_1, N_2, N_3 can now be solved for by use of the following matrix:

$$\begin{bmatrix} Ix & Ixy & \\ Ixy & Iy & \\ & & \sum A \end{bmatrix} \times \begin{bmatrix} N_1 \\ N_2 \\ N_3 \end{bmatrix} = \begin{bmatrix} -1 & & -\bar{Y} \\ & -1 & -\bar{X} \\ & & 1 \end{bmatrix} \times \begin{bmatrix} My \\ My \\ P \end{bmatrix}$$

TABLE (I)

Matrix A - Solution for Normal
Stress Coefficients

CHAPTER III

SHEAR FLOW COEFFICIENTS

In addition to thrust and moments, a section could very well carry torque and shear loads. The shear flow coefficients S_1 and S_2 are functions of the applied loads and section properties, as were N_1, N_2 and N_3 discussed in Chapter II. Therefore, each of these coefficients also has a constant value for each loading condition. Using the nomenclature shown in Figure (3-1), a solution will be set-up in matrix form to determine these coefficients.

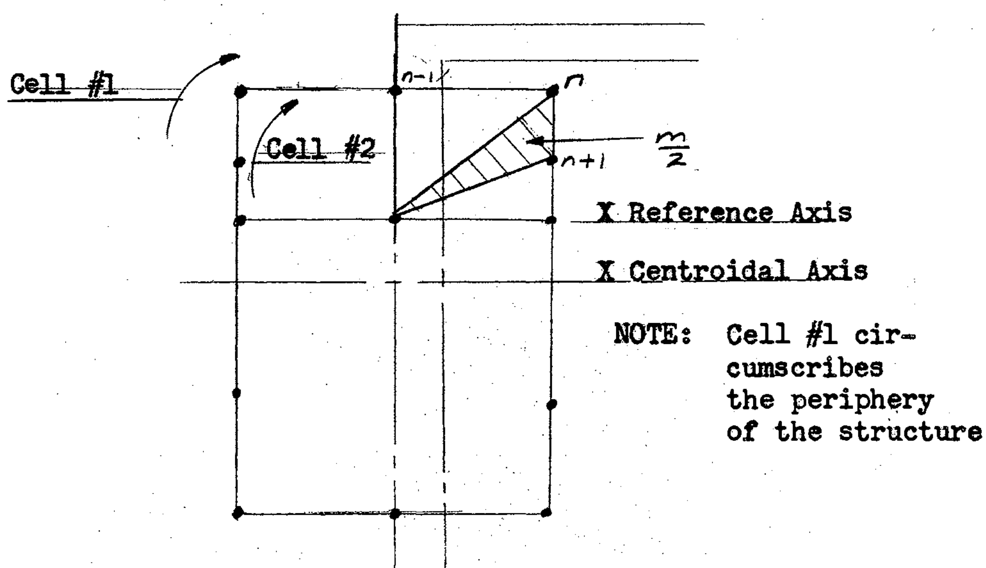


Figure (3-1)

Nomenclature for Typical Unsymmetrical Cross Section in Shear

The section is arbitrarily cut at element #1 assuming the shear flow is zero at that point. This results in an unbalanced shear.

fs' (unbalanced shear flow)

$$= \frac{-VIy + HIxy}{(Ixy)^2 - IxIy} \sum Ahy + \frac{VIxy - HIx}{(Ixy)^2 - IxIy} \sum Ahx \qquad (3\text{-}1)$$

For simplification, the following substitutions will be made:

$$S_1 = \frac{-VIy + HIxy}{Ixy^2 - IxIy} \qquad S_2 = \frac{-HIx + VIxy}{Ixy^2 - IxIy}$$

$$Qx = \sum Ahy \qquad Qy = \sum Ahx$$

Substituting into equation (3-1) we have fs' (unbalanced) =

$$S_1 Qx + S_2 Qy \qquad (3\text{-}4)$$

A single cell structure may be balanced by equating the torsional moment of the internal shear system to the external torque. For a mult-cell structure we have the additional condition that the twist ϕ is the same for each cell. These equations will now be developed.

$$S_1 \sum Qxm + S_2 \sum Qym + \sum (T^q \sum {}^q m) = T \text{ (external torque)}$$

$$\sum (T^q \sum {}^q m) = T - S_1 \sum Qxm - S_2 \sum Qym$$

Letting $\sum Qxm = Tx$ and $\sum Qym = Ty$

$$\sum (T^q \sum {}^q m) = T - S_1\, Tx - S_2\, Ty \qquad (3\text{-}5)$$

T^q is a torsional equilibrium constant which must be added to each cell. "q" is a superscript of primes equal in number to the cell number in which it will act. For instance, if we had three cells it would be necessary to add a constant shear flow T' to cell one, T" to cell two and T"' to cell three. If we were to analyze the structure as shown in Figure (3-1) we would find it necessary to write two equations in order to solve for T' and T". Equation (3-5) would satisfy one condition. Now a second equation must be written which equates the twists of the two cells.

$$\phi' = \phi'' = \frac{\sum' (fs \frac{ds}{Gt})}{\sum' m} = \frac{\sum'' (fs \frac{ds}{Gt})}{\sum'' m}$$

Since fs (balanced) = $S_1 Qx + S_2 Qy + T' + T''$

Then

$$S_1 \frac{\Sigma'(Qxms)}{\Sigma' m} + S_2 \frac{\Sigma'(Qyms)}{\Sigma'' m} - S_1 \frac{\Sigma''(Qxms)}{\Sigma'' m} - S_2 \frac{\Sigma''(Qyms)}{\Sigma'' m}$$

$$+ T' \frac{(\Sigma' ms)}{\Sigma' m} + T'' \frac{(\Sigma_{,}'' ms)}{\Sigma' m} - T'' \frac{(\Sigma'' ms)}{\Sigma'' m} - T' \frac{(\Sigma_{,}'' ms)}{\Sigma'' m} = 0$$

Where

Σ' = Sum of all elements in cell #1

Σ'' = Sum of all elements in cell #2

$\Sigma_{,}''$ = Sum of all elements common to both cells

Combining like terms we have

$$S_1 \left[\frac{\Sigma'(Qxms)}{\Sigma' m} - \frac{\Sigma''(Qxms)}{\Sigma'' m} \right] + S_2 \left[\frac{\Sigma'(Qyms)}{\Sigma'' m} - \frac{\Sigma''(Qyms)}{\Sigma'' m} \right]$$

$$+ T' \left[\frac{\Sigma' ms}{\Sigma' m} - \frac{\Sigma_{,}'' ms}{\Sigma'' m} \right] + T'' \left[\frac{\Sigma_{,}'' ms}{\Sigma' m} - \frac{\Sigma'' ms}{\Sigma'' m} \right]$$

Let $R'' = \dfrac{\Sigma' m}{\Sigma'' m}$

$$G_1'' = \Sigma' ms - R'' \Sigma_{,}'' ms$$

$$G_2'' = \Sigma_{,}'' ms - R'' \Sigma'' ms$$

$$Tx' = \Sigma'(Qxms)$$

$$Tx'' = \Sigma''(Qxms)$$

$$Ty' = \Sigma'(Qyms)$$

$$Ty'' = \Sigma''(Qyms)$$

$$\overline{T}x'' = Tx' - R'' Tx''$$

$$\overline{T}y'' = Ty' - R'' Ty''$$

$$\therefore S_1 \overline{T}x'' + S_2 \overline{T}y'' + T' G_1'' + T'' G_2'' = 0 \qquad (3\text{-}6)$$

The shear flow fs in pounds per inch at the $(n)^{th}$ element, for Figure (3-1), can now be expressed as follows:

fs (elements common to both cells) = $S_1Qx + T' + T''$

fs (elements only in cell one) = $S_1Qx + S_2Qy + T'$

fs (elements only in cell two) = $S_1Qx + S_2Qy + T''$

A three cell structure would require the additional term T''', a fourth cell the additional term T''''. etc.

The shear stress coefficients S_1, S_2, T', and T'' will be computed by use of the following matrix.

Ix	Ixy				S_1		V
Ixy	Iy			X	S_2	=	H
Ty	Ty	m	m		T_1		T
$\bar{\bar{T}}x''$	$\bar{\bar{T}}y''$	G_1''	G_2''		T		

TABLE II

Matrix B - Solution for Shear Flow Coefficients

Combining Matrices A and B we obtain the following:

Ix	Ixy							S_1		1							V
Ixy	Iy							S_2			1						H
Tx	Ty	$\Sigma m'$	$\Sigma m''$					T'				1					T
$\bar{\bar{T}}x$	$\bar{\bar{T}}y$	G_1''	G_2''				X	T''	=							X	
				Ix	Ixy			N_1					-1		$-\bar{\bar{Y}}$		Mx
				Ixy	Iy			N_2						-1	$-\bar{\bar{X}}$		My
						ΣA		N_3							1		P

TABLE III

Matrix C - Solution for Combined Shear Flow and Normal Stress Coefficients

CHAPTER IV

INPUT TABLES AND INSTRUCTIONS FOR ANALYST

The input tables, Tables IV and V, are filled out completely by the analyst and then turned over to the computer operator for processing. Of couse, the accuracy of the solution will depend upon a thorough understanding by the analyst of what each column requires as well as a correct interpretation of every column by the computer operator when initially coding the program into the machine. Therefore, Chapter IV will deal with the procedure to be followed by the analyst when filling out the Geometry and Load Tables, and Chapter V will deal with the instructions to the computer.

TABLE IV

GEOMETRY TABLE FOR A 2 CELL STRUCTURE

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
STA	ELEM NO	B	$\overline{B}$	Al	t	X	Y	C'	C''

TABLE V

LOAD TABLE

(1)	(2)	(3)	(4)	(5)	(6)	(7)
CASE	Mx	My	P	V	H	T

I. Geometry Table

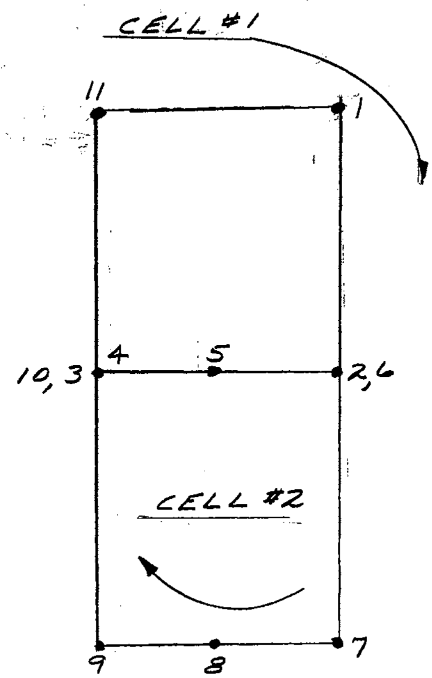


Figure (4-1)

Element Designation

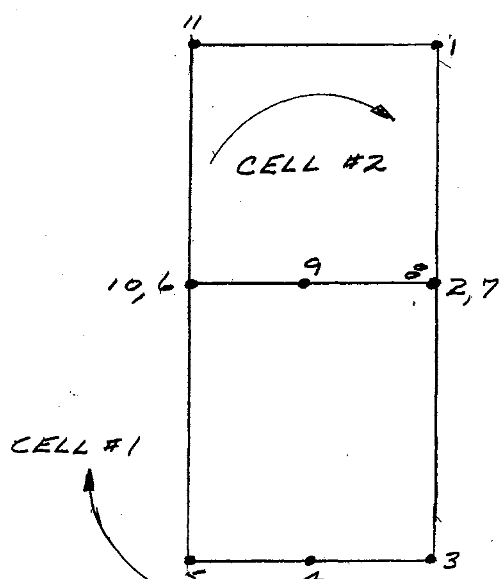


Figure (4-2)

Element Designation

A. Column 1

Sta number is an identification number for the section being analyzed.

B. Column 2

An element by definition is a longitudinal stringer plus the area of effective skin acting with it. The elements for each cell must be listed consecutively in a clockwise direction around the periphery. Cell #1 always extends around the outer periphery. For Figures (4-1) and (4-2), cell two can be in either the upper or lower box. In order to maintain a clockwise direction for every cell it is necessary to double number certain elements. Jumping across the structure causes counterclockwise direction, however, a zero element area combined with a zero effectivity factor (B, $\overline{B}$) cancels out the error.

C. Column 3

B (normal stress effectivity factor) is a factor to be used by the analyst to handle small openings or discontinuties in the section. It also eliminates any error caused by double numbering of certain elements.

D. Column 4

$\bar{B}$ (shear stress effectivity factor) is to be used in the same manner as B.

E. Columns 5 to 8

These columns are obvious by definition.

F. Column 9

C^{I} is a code for cell #1. When the element is in cell #1, $C^{I} = 1$. When the element is not in cell #1, $C_1 = 0$.

G. Column 10

C^{II} is a code for cell #2. $C^{II} = 0$ when the element is not in cell #1 or #2. $C^{II} = 1$ for all elements in cell #2 but not in cell #1. $C^{II} = 2$ when $C^{I} = 1$ and the element lies outside cell #2. $C^{II} = 3$ when the element is common to both cells.

II. Load Table

A. Column 1

Every station is capable of having several loading cases. The case number is an identification number assigned by the analyst.

B. Columns 2 to 7

These columns are for external applied loads. All loads are applied at the reference X or Y axis. If the shears are initially applied elsewhere, they should be transferred to the reference axis along with their corresponding moments.

CHAPTER V

EQUATIONS AND INSTRUCTIONS FOR COMPUTER

I. Section Property Analysis

A. Equations

$$dy_n = -Y_n + Y_{n+1} \qquad (5\text{-}1)$$

$$dx_n = -X_n + X_{n+1} \qquad (5\text{-}2)$$

$$ds_n = \sqrt{(dy_n)^2 + (dx_n)^2} \qquad (5\text{-}3)$$

$$Asc_n = -.15\left[t_n^2 + (t_{n-1})^2\right] \qquad (5\text{-}4)$$

$$Ast_n = .5\left[t_n(ds_n) + t_{n-1}(ds_{n-1})\right] \qquad (5\text{-}5)$$

$$A_n = (A1 - Asc) \text{ when R is negative} \qquad (5\text{-}6)$$

$$A_n = (A1 + Ast) \text{ when R is positive} \qquad (5\text{-}7)$$

$$\overline{Y} = \frac{\sum AY}{\sum A} \qquad (5\text{-}8)$$

$$\overline{X} = \frac{\sum AX}{\sum A} \qquad (5\text{-}9)$$

$$M\overline{x} = Mx + P\overline{Y} \qquad (5\text{-}10)$$

$$M\overline{y} = My + P\overline{X} \qquad (5\text{-}11)$$

$$hx_n = X_n - \overline{X} \qquad (5\text{-}12)$$

$$hy_n = Y_n - \overline{Y} \qquad (5\text{-}13)$$

$$Ix = \sum A(hy)^2 \qquad (5\text{-}14)$$

$$Iy = \sum A(hx)^2 \qquad (5\text{-}15)$$

$$Ixy = \sum A(hxhy) \qquad (5\text{-}16)$$

$$K_1 = \frac{M\overline{y}1x - M\overline{x}1xy}{\sqrt{(M\overline{y}1x - M\overline{x}1xy)^2 + (M\overline{x}1y - M\overline{y}1xy)^2}} \qquad (5\text{-}17)$$

$$K_2 = \frac{M\bar{x}ly - M\bar{y}lxy}{\sqrt{(M\bar{y}lx - M\bar{x}lxy)^2 + (M\bar{x}ly - M\bar{y}lxy)^2}} \qquad (5\text{-}18)$$

$$R_n = = K_2 hy_n - K_1 hx_n \qquad (5\text{-}19)$$

B. Procedure

1. Solve for dy, dx, and ds for every element (Equations (5-1) to (5-3))
2. Solve for Asc and Ast for every element (Equations (5-4) and (5-5))

   NOTE: If Al = 0, Asc = 0
3. Using A_n = (Al + Ast) solve equations (5-8) to (5-16)
4. Solve for K_1 and K_2 (Equations (5-17) and (5-18)) using results of step 3. Use only + value of the radical
5. Solve for R by substituting $M\bar{y}$ and $M\bar{x}$ with their appropriate sign into Equation (5-19)
6. Select Asc_n or Ast_n that acts with the element ($-R_n$ selects Asc_n, $+R_n$ selects Ast_n)
7. Compute A_n for every element according to the sign of R
8. Repeat steps 3 to 5 using A_n as found in step 7
9. Any R which has a different sign than its original R value must have its corresponding Asc or Ast changed to agree with its new sign.
10. This procedure is repeated until this sign change no longer occurs.

II. Stress Coefficients

A. Equations

Qx'_n = Progressive $\sum_1^n (Ahy)$. Omit all elements have $C' = 0$.

Add only Ahy's for $C' = 1$. (5-20)

$Qx_n'' = \text{Progressive} \sum_1^n (Ahy)$. Omit all elements having $C'' = .0$.

Add only Ahy's for $C'' = 1$. (5-21)

$Qx_n = Qx_n' + Qx_n''$ (5-22)

$Qy_n' = \text{Progressive} \sum_1^n (Ahx)$. Omit all elements having $C' = 0$.

Add only Ahx's for $C' = 1$. (5-23)

$Qy_n'' = \text{Progressive} \sum_1^n (Ahx)$. Omit all elements having $C'' = 0$.

Add only Ahx's for $C'' = 1$. (5-24)

$$Qy_n = Qy_n' + Qy_n'' \quad (5\text{-}25)$$

$$M_n' = Y_n dx_n - X_n dy_n \quad (5\text{-}26)$$

$$M_n'' = Y_n dx_n - X_n dy_n \quad (5\text{-}27)$$

$$R'' = \frac{\sum' m}{\sum'' m} \quad (5\text{-}28)$$

$$ms_n = \frac{ds_n}{Gt_n} \quad (5\text{-}29)$$

$$Ty = \sum (Qym) \quad (5\text{-}30)$$

$$Tx = \sum (Qxm) \quad (5\text{-}31)$$

$$G_1'' = \sum' ms - R'' \sum_1'' ms \quad (5\text{-}32)$$

$$G_2 = \sum_{,}'' ms - R'' \sum'' ms \quad (5\text{-}33)$$

$$Tx' = \sum' (Qxms) \quad (5\text{-}34)$$

$$Tx'' = \sum'' (Qxms) \quad (5\text{-}35)$$

$$Ty' = \sum' (Qyms) \quad (5\text{-}36)$$

$$Ty'' = \sum'' (Qyms) \quad (5\text{-}37)$$

$$\overline{Tx}'' = Tx' - R'' Tx'' \quad (5\text{-}38)$$

$$\overline{Ty}'' = Ty' - R'' Ty'' \quad (5\text{-}39)$$

B. Procedure

1. Perform the following operations for the given values of C'

(a) When $C' = 1$

1. Add $A_n hx_n$ to Qy'_{n-1} Equation (5-23)
2. Add $A_n hy_n$ to Qx'_{n-1} Equation (5-20)
3. $\sum' m_n$ Equation (5-26)

(b) When $C' = 0$

1. Omit Qy'_n Equation (5-23)
2. Omit Qx'_n Equation (5-20)
3. Do not $\sum' m_n$ Equation (5-26)

2. Perform the following operations for the given values of C''

(a) When $C'' = 0$

1. Omit Qy''_n Equation (5-24)
2. Omit Qx''_n Equation (5-21)
3. Do not $\sum'' m_n$ Equation (5-27)

(b) When $C'' = 1$

1. Add $A_n hx_n$ to Qy''_{n-1} Equation (5-24)
2. Add $A_n hy_n$ to Qx''_{n-1} Equation (5-21)
3. $\sum'' m_n$ Equation (5-27)

(c) When $C'' = 2$

1. Carry previous Qy_{n-1}--do not add $A_n hx_n$ to Qy''_{n-1} Equation (5-24)
2. Carry previous Qx_{n-1}--do not add $A_n hy_n$ to Qx''_{n-1} Equation (5-21)
3. Do not $\sum'' m_n$ Equation (5-27)

(d) When $C'' = 3$

1. Carry previous Qy''_{n-1}--do not add $A_n hx_n$ to Qy''_{n-1}
Equation (5-24)

2. Carry previous Qx_{n-1}--do not add $A_n hx_n$ to Qx''_{n-1}
Equation (5-21)

3. $\Sigma'' m$ Equation (5-27)

3. Solve Equations (5-22) and (5-25) for Qx_n and Qy_n for every element.

4. Solve Equation (5-28) for R'' where Σ' = sum of all elements have $C' = 1$ and Σ'' = sum of all elements having $C'' = 1$ or 3.

5. Solve Equation (5-29) for ms_n for every element

6. Solve Equations (5-30) to (5-39) where Σ' and Σ'' have same meaning as in step 4. Σ indicates the total summation of all elements.

7. Having solved for the section properties (Equations (5-1) to (5-19)) and the stress coefficients (Equations (5-20) to (5-39)) the following matrix can now by solved.

MATRIX C

Ix	Ixy					
Ixy	Iy					
Tx	Ty	$\Sigma' m$	$\Sigma'' m$			
$\bar{T}x''$	$\bar{T}y''$	G_1''	G_2''			
				Ix	Ixy	
				Ixy	Iy	
						ΣA

X

S_1
S_2
T
T
N_1
N_2
N_3

=

1					
	1				
		1			
			-1		$-\bar{Y}$
				-1	$-\bar{X}$
					1

X

V
H
T
Mx
My
P

III. Stress Equations

A. Equations

$$fN_n = \left[N_1 hy_n + N_2 hx_n + N_3\right] B \qquad (5\text{-}40)$$

$$fs_n = \left[S_1 Qx_n + S_2 Qy_n + T' + T''\right] \overline{B} \qquad (5\text{-}41)$$

$$fs_n = \left[S_1 Qx_n + S_2 Qy_n + T'\right] \overline{B} \qquad (5\text{-}42)$$

$$fs_n = \left[S_1 Qx + S_2 Qy + T''\right] \overline{B} \qquad (5\text{-}43)$$

B. Procedure

1. Solve Equation (5-40) for all elements
2. Solve Equation (5-41) for all elements with $C' = 1$, $C'' = 3$
3. Solve Equation (5-42) for all elements with $C' = 1$, $C'' = 2$
4. Solve Equation (5-43) for all elements with $C' = 0$, $C'' = 1$

CHAPTER VI

INTERPRETATION OF RESULTS

Once this program has been coded into the automatic tabulating machine it will be a simple matter for an analyst to solve for the shear flows and normal stresses for any two cell semi-monocoque structure. The analyst is required to code the geometry of the section in a tabular form and submit this table, along with the applied loads, to the automatic tabulating machine operator. Using a series of equations, the automatic tabulating machine solves for the centroidal axis, section properties, and stress coefficients. The final phase prints out the shear flows and normal stresses.

Although this report outlines in detail the coding and equations for a two cell structure, very little has been said about how to proceed if there were more than two cells. If such were the case, it would be a matter of expanding this report so that it would handle the situation. This would require an additional torsional equilibrium constant (T^q) for each additional cell. This constant could be found by equating the twist ϕ^q of the additional cell to the twist of one of the other cells. Therefore, Matrix C, Page 8, would have an extra row and column for each additional cell. The coding system would also have to be expanded so as to include a C^q term for each additional cell in the input table (Page 10). All the elements in the additional cell would have to be coded by expanding the coding system as set up on Pages 17, 18 so as to include the elements in the additional cell when solving for Q and m. And finally, a shear flow equation would have to be written for each additional cell. The number of cells that can be added in this manner is limited only by the storage space of the automatic tabulation equipment which varies with each made and model.

As a suggestion for future study, I would recommend an expansion of this thesis so as to handle large openings either in or nearby the section being analyzed.

BIBLIOGRAPHY

1. Bruhn, E. F., Analysis and Design of Aircraft Structures (Tri-State Offset Company: Ohio, 1937).

2. Perry, D. G., Aircraft Structures (McGraw-Hill: New York, 1949).

3. Seeley, F. B. and Smith, J. O., Advanced Mechanics of Materials (Wiley: New York, 1955).

4. Kuhn, Paul, Stresses in Aircraft and Shell Structures (McGraw-Hill: New York, 1956).

5. Timoshenko, S., Theory of Elastic Stability (McGraw-Hill: New York, 1936).

6. Gerard, G. and Becker, H., "Buckling of Curved Plates and Shells" (NACA 3783, 1951).

APPENDIX

APPENDIX

EXAMPLE PROBLEM

Loads:

Mx = +1,000,000

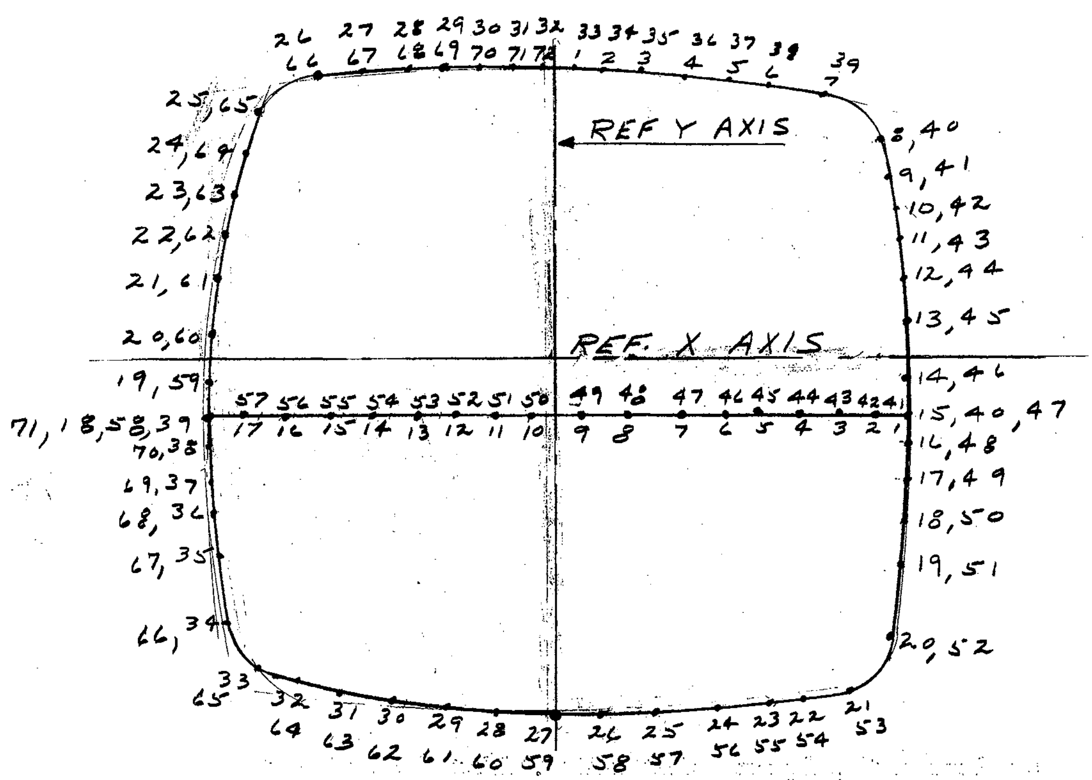
My = +3,000,000

P = +200,000

T = +200,000

V = 10,000

H = 20,000



Either numbering system is acceptable. For this example, the numbers starting at the right side of the inner web will be used.

GEOMETRY SHEET

STA	ELEM NO	B	$\overline{B}$	A1	t	X	Y	C'	C''
20	1	1.0	1.0	0	.040	42.90	-10.19	0	1
	2			.125		38.20			
	3					33.50			
	4					28.80			
	5					24.10			
	6					19.40			
	7					14.70			
	8					10.00			
	9					5.00			
	10					- 5.00			
	11					-10.00			
	12					-14.70			
	13					-19.40			
	14					-24.10			
	15					-28.80			
	16					-33.50			
	17			.125		-38.20		0	1
	18			.250		-42.90	-10.19	1	3
	19					-42.99	- 3.50		
	20					-43.00	1.50		
	21					-42.96	7.02		
	22					-42.81	13.00		
20	23	1.0	1.0	.250	.040	-42.56	18.50	1	3

GEOMETRY SHEET (Continued)

STA	ELEM NO	B	$\bar{B}$	A1	t	X	Y	C'	C''
20	24	1.0	1.0	.250	.040	-41.99	24.94	1	3
	25					-40.79	31.59		
	26					-35.05	41.03		
	27					-29.79	43.56		
	28					-24.64	44.73		
	29					-19.08	45.39		
	30					-13.05	45.73		
	31					- 8.10	45.92		
	32					- 2.76	45.99		
	33					2.76	45.99		
	34					8.10	45.92		
	35					13.05	45.73		
	36					19.08	45.39		
	37					24.64	44.73		
	38					29.79	43.56		
	39					35.05	41.03		
	40					40.79	31.59		
	41					41.99	24.94		
	42					42.56	18.50		
	43					42.81	13.00		
	44					42.96	7.02		
	45					43.00	1.50		
	46					42.99	- 3.50		
20	47	1.0	1.0	.250	.040	42.90	-10.19	1	3

GEOMETRY SHEET (Continued)

STA	ELEM NO	B	$\overline{B}$	A1	t	X	Y	C'	C"
20	48	1.0	1.0	.250	.040	42.67	-16.63	1	2
	49					42.17	-23.31		
	50					41.34	-29.17		
	51					39.73	-34.81		
	52					34.40	-41.48		
	53					29.40	-45.60		
	54					22.35	-47.70		
	55					18.32	-48.00		
	56					12.80	-48.22		
	57					7.75	-48.50		
	58					4.30	-49.00		
	59					0.00	-49.00		
	60					- 4.30	-49.00		
	61					- 7.75	-48.50		
	62					-12.80	-48.22		
	63					-18.32	-48.00		
	64					-22.35	-47.70		
	65					-29.40	-45.60		
	66					-34.40	-41.48		
	67					-39.73	-34.18		
	68					-41.34	-29.17		
	69					-42.17	-23.31		
	70	1.0	1.0	.250	.040	-42.67	-16.63	1	2
20	71	0	0	0	0	-42.90	-10.19	0	0

LOAD SHEET

CASE	Mx	My	P	V	H	T
1	1000000	0	200000	10000	20000	2000000

	SHELL	ANAL.	PHASE	ZERO	
STA.	COMP.	SIG. A	X BAR	Y Bar	
30.000	1	24.184	7.30-	4.88-	
S.N.	X	Y	A-L	A-S	A
1	42.90	10.19-	.000	.000	.000
2	38.20	10.19-	.125	.048	.173
3	33.50	10.19-	.125	.048	.173
4	28.80	10.19-	.125	.048	.173
5	24.10	10.19-	.125	.048	.173
6	19.40	10.19-	.125	.048	.173
7	14.70	10.19-	.125	.048	.173
8	10.00	10.19-	.125	.048	.173
9	5.00	10.19-	.125	.048	.173
10	5.00-	10.19-	.125	.048	.173
11	10.00-	10.19-	.125	.194	.319
12	14.70-	10.19-	.125	.188	.313
13	19.40-	10.19-	.125	.188	.313
14	24.10-	10.19-	.125	.188	.313
15	28.80-	10.19-	.125	.188	.313
16	33.50-	10.19-	.125	.188	.313
17	38.20-	10.19-	.125	.188	.313
18	42.90-	10.19-	.250	.227	.477
19	42.99-	3.50-	.250	.233	.483
20	43.00-	1.50	.250	.210	.460
21	42.96-	7.02	.250	.230	.480
22	42.81-	13.00	.250	.229	.479

	SHELL	ANAL.	PHASE	ZERO	
STA.	COMP.	SIG. A	X BAR	Y BAR	
30.000	1	24.184	7.30-	4.88-	
S.N.	X	Y	A-L	A-S	A
23	42.56-	18.50	.250	.239	.489
24	41.99-	24.94	.250	.264	.514
25	40.79-	31.59	.250	.356	.606
26	35.05-	41.03	.250	.337	.587
27	29.79-	43.56	.250	.222	.472
28	24.64-	44.73	.250	.217	.467
29	19.08-	45.39	.250	.048	.298
30	13.05-	45.73	.250	.048	.298
31	8.10-	45.92	.250	.048	.298
32	2.76-	45.99	.250	.048	.298
33	2.76	45.99	.250	.048	.298
34	8.10	45.92	.250	.048	.298
35	13.05	45.73	.250	.048	.298
36	19.08	45.39	.250	.048	.298
37	24.64	44.73	.250	.048	.298
38	29.79	43.56	.250	.048	.298
39	35.05	41.03	.250	.048	.298
40	40.79	31.59	.250	.048	.298
41	41.99	24.94	.250	.048	.298
42	42.56	18.50	.250	.048	.298
43	42.81	13.00	.250	.048	.298
44	42.96	7.02	.250	.048	.298

	SHELL	ANAL.	PHASE	ZERO	
STA	COMP.	SIG. A	X BAR	Y BAR	
30.000	1	24.184	7.30-	4.88-	
S.N.	X	Y	A-L	A-S	A
45	43.00	1.50	.250	.048	.298
46	42.99	3.50-	.250	.048	.298
47	42.90	10.19-	.250	.048	.298
48	42.67	16.63-	.250	.048	.298
49	42.17	23.31-	.250	.048	.298
50	41.34	29.17-	.250	.048	.298
51	39.73	34.81-	.250	.048	.298
52	34.40	41.48-	.250	.048	.298
53	29.40	45.60-	.250	.048	.298
54	22.35	47.70-	.250	.048	.298
55	18.32	48.00-	.250	.048	.298
56	12.80	48.22-	.250	.048	.298
57	7.75	48.50-	.250	.048	.298
58	4.30	49.00-	.250	.155	.405
59	.00	49.00-	.250	.172	.422
60	4.30-	49.00-	.250	.155	.405
61	7.75-	48.50-	.250	.171	.421
62	12.80-	48.22-	.250	.211	.461
63	18.32-	48.00-	.250	.191	.441
64	22.35-	47.70-	.250	.228	.478
65	29.40-	45.60-	.250	.276	.526
66	34.40-	41.48-	.250	.300	.550

	SHELL	ANAL.	PHASE	ZERO	
STA	COMP.	SIG. A	X BAR	Y BAR	
30.000	1	24.184	7.30-	4.88-	

S.N.	X	Y	A-L	A-S	A
67	39.73-	34.81-	.250	.288	.538
68	41.34-	29.17-	.250	.235	.485
69	42.17-	23.31-	.250	.252	.502
70	42.90-	10.19-	.000	.128	.128

30	20.0	1		
	hx	Qy	hy	Qx
1	50.204	.00	5.307-	.00-
2	45.504	7.87	5.307-	.92-
3	40.804	14.93	5.307-	1.84-
4	36.104	21.18	5.307-	2.75-
5	31.404	26.61	5.307-	3.67-
6	26.704	31.23	5.307-	4.59-
7	22.004	35.04	5.307-	5.51-
8	17.304	38.03	5.307-	6.43-
9	12.304	40.16	5.307-	7.34-
10	2.304	40.56	5.307-	8.26-
11	2.696-	39.70	5.307-	9.96-
12	7.396-	37.38	5.307-	11.62-
13	12.096-	33.60	5.307-	13.28-
14	16.796-	28.34	5.307-	14.94-
15	21.496-	21.61	5.307-	16.60-
16	26.196-	13.41	5.307-	18.26-
17	30.896-	3.74	5.307-	19.92-
18	35.596-	13.24-	5.307-	22.45-
19	35.686-	30.48-	1.383	21.78-
20	35.696-	46.90-	6.383	18.85-
21	35.656-	64.01-	11.903	13.13-
22	35.506-	81.02-	17.883	4.57-
23	35.256-	98.26-	23.383	6.87
24	34.686-	116.09-	29.823	22.20

30	20.0	1		
	hx	Qy	hy	Qx
25	33.486-	136.38-	36.473	44.30
26	27.756-	152.67-	45.913	71.25
27	22.486-	163.28-	48.443	94.11
28	17.336-	171.38-	49.613	117.28
29	11.776-	174.89-	50.273	132.27
30	5.746-	176.60-	50.613	147.35
31	.796-	176.84-	50.803	162.49
32	4.544	175.48-	50.873	177.65
33	10.064	172.49-	50.873	192.81
34	15.404	167.89-	50.803	207.95
35	20.354	161.83-	50.613	223.03
36	26.384	153.97-	50.273	238.01
37	31.944	144.45-	49.613	252.80
38	37.094	133.39-	48.443	267.23
39	42.354	120.77-	45.913	280.91
40	48.094	106.44-	36.473	291.78
41	49.294	91.75-	29.823	300.67
42	49.864	76.89-	23.383	307.64
43	50.114	61.96-	17.883	312.97
44	50.264	46.98-	11.903	316.52
45	50.304	31.99-	6.383	318.42
46	50.294	17.00-	1.383	318.83
47	50.204	2.04-	5.307-	317.25
48	49.974	9.11	11.747-	333.67

30 20.0 1

	hx	Qy	hy	Qx
49	49.474	23.85	18.427-	328.18
50	48.644	38.35	24.287-	320.94
51	47.034	52.37	29.927-	312.02
52	41.704	64.79	36.597-	301.12
53	36.704	75.73	40.717-	288.98
54	29.654	84.56	42.817-	276.22
55	25.624	92.20	43.117-	263.38
56	20.104	98.20	43.337-	250.46
57	15.054	102.68	43.617-	237.46
58	11.604	107.38	44.117-	219.60
59	7.304	110.46	44.117-	200.98
60	3.004	111.68	44.117-	183.11
61	.446-	111.49	43.617-	164.75
62	5.496-	108.96	43.337-	144.77
63	11.016-	104.10	43.117-	125.76
64.	15.046-	96.91	42.817-	104.29
65	22.096-	85.28	40.717-	83.87
66	27.096-	70.38	36.597-	63.74
67	32.426-	52.94	29.927-	47.64
68	34.036-	36.43	24.287-	35.87
69	34.866-	18.92	18.427-	26.61
70	35.366-	.82	11.747-	20.60
71	35.596-	3.74-	5.307-	19.92

STATION 30 20.0 INCHES COMPRESSION NUMBER 1

X-BAR	Y-BAR	SUM-A
7.304-	4.883-	24.184

D MATRIX

$(\Sigma' \frac{ds}{Gt})$ 7918.00 4597.00 $(\Sigma'' \frac{ds}{Gt})$

6742.00 $(\Sigma' \frac{ds}{Gt})$

M MATRIX

$(\Sigma' m)$ 14137.51 9367.99 $(\Sigma'' m)$

R MATRIX

1.50913 (R'')

G MATRIX

.0 980.6 (G_1'')

.0 5577.5- (G_2'')

T MATRIX

(Ty) 463935.92- 2621663.20 (Tx)

(Ty') 273300.00- 1389328.00 (Tx')

(Ty'') 441104.00- 753744.00 (Tx'')

STATION 30 20.0 INCHES COMPRESSION NUMBER 1

T-BAR MATRIX

($\bar{T}y''$)	392382.65	251831.40	($\bar{T}x''$)

1 MATRIX

(1y)	23410	187-	(1xy)
(1xy)	187-	26630	(1x)

SOLUTION FOR MATRIX C

1	1	1	.26630000	5	.18700000-	3	.00000000	0	.00000000	
1	2	1	.18700000-	3	.23410000	5	.00000000	0	.00000000	
1	3	1	.26216632	7	.46393592-	6	.14137500	5	.93680000	
1	4	1	.25183140	6	.39238265	6	.00000000	0	.55775000-	
1	6	1	.00000000	0	.00000000	0	.00000000	0	.00000000	
1	7	1	.00000000	0	.00000000	0	.00000000	0	.00000000	

0	.00000000	0	.00000000	0	1	1	7	.00000000	0
0	.00000000	0	.00000000	0	1	2	7	.00000000	0
4	.00000000	0	.00000000	0	1	3	7	.00000000	0
4	.00000000	0	.00000000	0	1	4	7	.00000000	0
0	.24180000	2	.00000000	0	1	5	7	.00000000	0
0	.00000000	0	.26630000	5	1	6	7	.18700000-	3
0	.00000000	0	.18700000-	3	1	7	7	.23410000	5

1001	1	1	.10000000	5
1001	2	1	.20000000	5
1001	3	1	.20000000	5
10001	4	1	.00000000	0
1001	5	1	.10000000	4
1001	6	1	.99512000-	6
1001	7	1	.29927000-	7

2001	1	1	.38153702	0	Solution
2001	2	1	.85738348	0	
2001	3	1	.92585607-	2	
2001	4	1	.77544670	2	
2001	5	1	.41356493	2	
2001	6	1	.38268230-	2	
2001	7	1	.12814422-	3	
3001	1	1	.10000000	5	Check
3001	2	1	.20000000	5	
3001	3	1	.20000011	5	
3001	4	1	.51065775	2-	
3001	5	1	.10000000	4	
3001	6	1	.99511999-	6	
3001	7	1	.29927000-	7	

	STA 0 20.0 COND 01		STA 0 .0 COND .00		STA 0 .0 COND 00	
	F-S	F-N	F-S	F-N	F-S	F-N
1	78	6188-				
2	84	5586-				
3	90	4984-				
4	94	4382-				
5	99	3779-				
6	103	3177-				
7	105	2575-				
8	108	1972-				
9	109	1332-				
10	109	50-				
11	108	590				
12	105	1192				
13	101	1794				
14	96	2396				
15	90	2999				
16	82	3601				
17	73	4203				
18	35-	4806				
19	49-	4561				
20	63-	4371				
21	75-	4155				
22	86-	3907				
23	97-	3664				
24	106-	3345				

	STA 0 20.0 COND 01		STA 0 .0 COND 00		STA 0 .0 COND 00	
	F-S	F-N	F-S	F-N	F-S	F-N
25	115-	2936				
26	119-	1839				
27	119-	1069				
28	117-	364				
29	114-	373-				
30	110-	1159-				
31	105-	1800-				
32	98-	2487-				
33	89-	3195-				
34	80-	3876-				
35	69-	4503-				
36	56-	5263-				
37	43-	5950-				
38	27-	6565-				
39	11-	7143-				
40	5	7517-				
41	21	7416-				
42	37	7243-				
43	51	7064-				
44	66	6855-				
45	79	6649-				
46	92	6456-				
47	104	6188-				
48	43	5913-				

			STA 0 .0 COND 00		STA 0 .0 COND 00	
			F-S	F-N	F-S	F-N
49	53	5593-				
50	63	5262-				
51	71	4840-				
52	78	3902-				
53	83	3103-				
54	85	2120-				
55	87	1592-				
56	87	876-				
57	86	218-				
58	83	242				
59	79	793				
60	73	1344				
61	66	1767				
62	56	2404				
63	45	3103				
64	31	3608				
65	13	4431				
66	8-	4914				
67	29-	5341				
68	48-	5332				
69	66-	5214				
70	84-	5022				
71	0-	0				

VITA

David G. Bahos

Candidate for the Degree of

Master of Science

Thesis: SHEAR FLOW AND NORMAL STRESS ANALYSIS OF MULTI-CELL SEMI-MONOCOQUE STRUCTURES BY HIGH SPEED COMPUTERS

Major Field: Civil Engineering

Biographical:

Personal Data: Born in Tulsa, Oklahoma, April 20, 1931, the son of Gus and Olga Bahos.

Education: Graduated from Tulsa Central High School in 1949; received the Bachelor of Science degree from the University of Oklahoma in 1954, with a major in Civil Engineering; completed requirements for Master of Science degree in August, 1960.

Professional Experience: Entered the United States Army in June, 1954, serving as a company commander of a construction unit of the Corps of Engineers. Employed as a stress analyst by Douglas Aircraft from April, 1956, to April, 1958. Presently employed by Sperry Utah Engineering Laboratory as Senior Project Engineer.