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PANASONIC MR-1800 HAND-HELD COMPUTER SOLUTIONS TO
COMPOSITE MATERIALS FOR (U) UNIVERSAL ENERGY SYSTEMS
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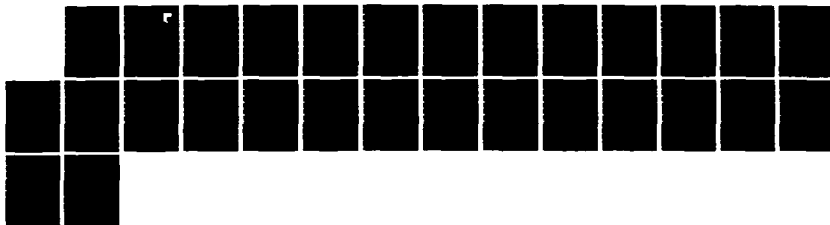
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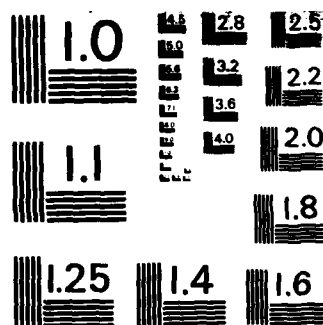
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PANASONIC HR-1800 HAND-HELD COMPUTER SOLUTIONS
TO COMPOSITE MATERIALS FORMULAS

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Nonmetallic Materials Division

and

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September 1983

Final Report for Period September 1982 - June 1983

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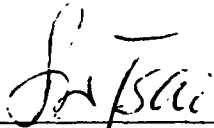
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This technical report has been reviewed and is approved for publication.



S.W. TSAI, Project Engineer & Chief
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FOR THE COMMANDER



F. D. CHERRY, Chief
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18. SUPPLEMENTARY NOTES This program uses the language of BASIC. The computer program(s) contained in this technical report is (are) theoretical and in no way reflect(s) any Air Force owned software programs.		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number) BASIC Programming Composite Materials Properties of Unidirectional and Laminated Composite In-Plane and Flexural Stiffness and Strength Buckling of Orthotropic Simply Support Plate		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) This volume contains the description and instructions of the use of Panasonic HR-1800 Hand-Held Computer for the key calculations of the stiffness and strength of symmetric laminated composites. Instant calculations can be made for practical use. The formulas and equation numbers used in the performed programming have been derived in a book entitled, <u>Introduction to Composite Materials</u> , co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, Connecticut, July 1980.		

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FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFWAL/MLBM), Nonmetallic Materials Division, Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio. This work was performed under Contract F33615-82-C-5001; SB5448-82-C-0086.

This time period covered by this report was from September 1982 to June 1983. Dr. Thierry N. Massard is a Visiting Scientist at the Materials Laboratory, Air Force Wright Aeronautical Laboratories, Wright-Patterson AFB, Ohio, and a Chief Engineer at the Commissari at L' Energie Atomique, Montrouge, France.

Dr. Won J. Park is a Senior Scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

The equations and table numbers which appear in the flow charts are the same as in Introduction to Composite Materials, co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, Connecticut, in July 1980.

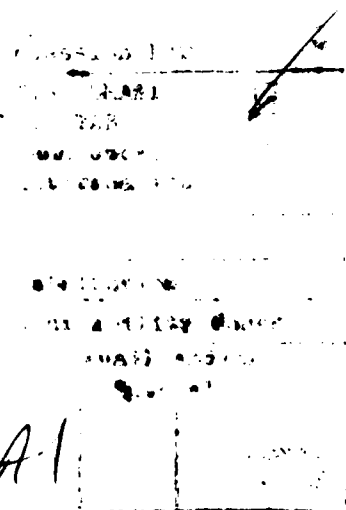


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SECTION I

USER GENERAL INSTRUCTION

- (1) The program language for HR-1800 Hand-Held Computer is BASIC from the Microsoft BASIC ROM attached to the computer.
- (2) The capacity of the computer is 8k RAM (model HR-1800). The printer is optional.
- (3) The program is called SYM-LAM (for symmetric laminates). The program considers only symmetric laminates of composite materials and is restricted to orthotropic materials for the buckling calculations.

SECTION II
CONTENTS OF THE PROGRAM

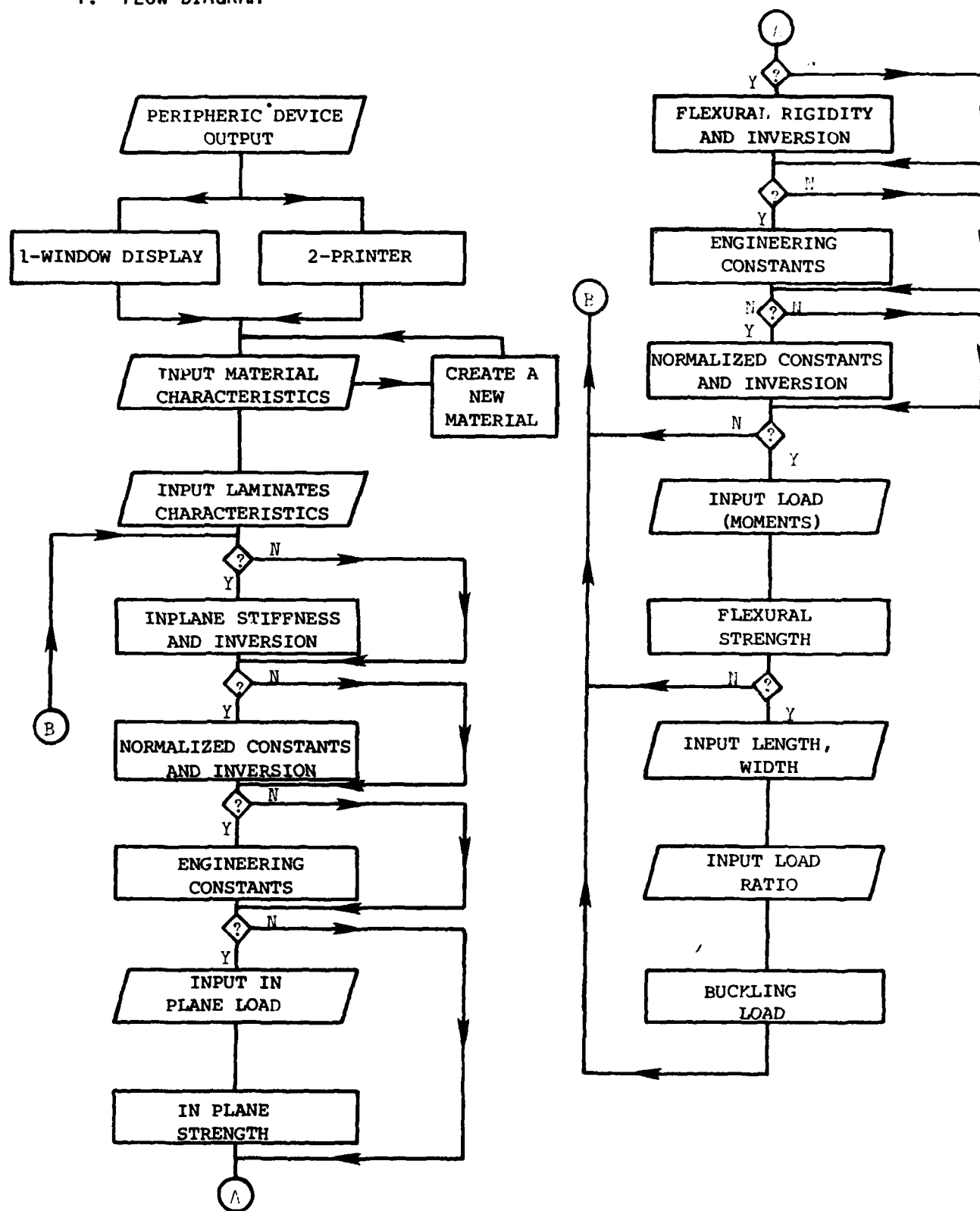
The program performs scientific operations and computations of composite materials.

- (1) In-plane stiffness of symmetric laminates and matrix conversion.
- (2) Engineering constants.
- (3) Normalized in-plane stiffness and matrix inversion.
- (4) In-plane strength of symmetric laminates.
- (5) Flexural stiffness of symmetric sandwich plate and matrix inversion.
- (6) Engineering flexural constants.
- (7) Normalized flexural rigidity of sandwich plate and matrix inversion.
- (8) Flexural strength of sandwich plate.
- (9) Buckling load and modes of a simply supported rectangular plate subjected to two axial loads. (ORTHOTROPIC MATERIALS ONLY)

Reference: Mechanics of Composite Materials, R. M. Jones, MacGraw Hill .

SECTION III
PROCEDURE

1. FLOW DIAGRAM



2. KEY OPERATION PROCEDURE

Display	Operation	Print Out & Remarks
	R U N	can be a function key f_1 or f_2 or f_3
1 - LCD or 2 - printer	E N T E R	
	2 *	1 will give results on the display window 2 will give results on the printer
	E N T E R	
Material (m for menu)?	M *	Available data (4 materials) 1-T300/5208 2-ALUMINIUM 3-KEVLAR/EPOXY 4-GLASS/EPOXY Instructions to create new materials data TO INPUT A NEW MATERIAL (number N) - TYPE THE FOLLOWING LINE: 10*N DATA Ex,Ey,vx,Es,t,X X',Y, Y', S - INCREMENT N IN LINE 1820
Material (m for menu)?	1 *	the laminate can use only one material
	E N T E R	T300/5208
No. of angles	2 *	definition of the laminate
	E N T E R	
	90 *	the laminate is $[0_4/90_4]_S$
angle = ? number of plies = ?	E N T E R	layer nearer the midplane *****
	4 *	ANGLE 1 = 0 Number of plies = 4
	E N T E R	
angle = ? number of plies = ?	0 *	layer on the outside *****
	E N T E R	ANGLE 2 = 90 Number of plies = 4
	4 *	
	E N T E R	

*user' choice

Display	Operation	Print Out & Remarks
Number of Core Plies? (flexural)	0 * ENTER	The core has no mechanical property. The ply thickness is the same than the laminate of the faces.
In plane calculation -Y/N?	Y * ENTER	n. of core plies = 0 IN PLANE CONSTANTS STIFFNESS in MN/m A11 192.157298 A22 192.157298 A12 5.79384891 A66 14.34 A16 0 A26 0 ----- COMPLIANCE in m/KN a11 5.20880528 a22 5.20880528 a12 -.157053784 a66 69.7350069 a16 0 a26 0
Engineering CST Y/N?	Y * ENTER	ENGINEERING CONST. E1-o 95.991 GPa E2-o 95.991 GPa E6-o 7.17 GPa v21-o .03 v12-o .03 v61-o 0 v16-o 0 v62-o 0 v26-o 0

Display	Operation	Print Out & Remarks
Normalized Constants Y/N?	☐ Y *	
	ENTER	STIFFNESS in GPa A*11 96.0786488 A*22 96.0786488 A*12 2.89692445 A*66 7.17000001 A*16 0 A*26 0
		COMPLIANCE in TPa-1 a*11 10.4176106 a*22 10.4176106 a*12 -.314107569 a*66 139.470014 a*16 0 a*26 0
In plane strength Y/N?	☐ Y *	IN PLANE STRENGTH
	ENTER	N1 = 1 MN/m N2 = 0 MN/m N6 = 0 MN/m -----1----- angle 1 = 90 R+ = .746808548 n+ = 22 Sgm+ = 373.404274 MPa R- = 4.53828452 n- = 2 Sgm- = -2269.14226 MPa -----2-----
N1 = (MN/m)?	1 *	
	ENTER	
N2 = (MN/m)?	0 *	
	ENTER	
N6 = (MN/m)?	0 *	
	ENTER	angle 2 = 0 R+ = 1.36378965 n+ = 12 Sgm+ = 681.894823 MPa R- = 2.21547827 n- = 6 Sgm- = -1107.73914 MPa

Display	Operation	Print Out & Remarks
Flexural calculations Y/N?	☐ Y * ENTER	FLEXURAL CONSTANTS STIFFNESS in Nm D11 106.918678 D22 21.1861875 D12 1.93128297 D66 4.78000001 D16 0 D26 0 ----- COMPLIANCE in (Nm)-1 d11 9.36832861 d22 47.2784122 d12 -.853994778 d66 209.205021 d16 0 d26 0
Engineering CST Y/N?	☐ Y * ENTER	ENGINEERING CONST. E1-+ 160.113 GPa E2-f 31.726 GPa E6-f 7.17 GPa v21-f .091 v12-f .018 v61-f 0 v16-f 0 v62-f 0 v26-f 0
Normalized CST Y/N?	☐ Y * ENTER	STIFFNESS in GPa D*11 160.378016 D*22 31.7792812 D*12 2.89692445 D*66 7.17000001 D*16 0 D*26 0

Display	Operation	Print Out & Remarks
Flexural Strength Y/N? M1 = ? (MN) M2 = ? (MN) M6 = ? (MN)	☐ Y * ENTER	COMPLIANCE in TPa-l d*11 6.24555241 d*22 31.5189415 d*12-.569329852 d*66 139.470014 d*16 0 d*26 0 FLEXURAL STRENGTH M1 = 1 MN M2 = 0 MN M6 = 0 MN --- 1 ---- angle 1 = 90 R+ = 8.85874406E-04 Sgm+ = 253.81161 MPa R- = 4.31521825E-03 Sgm- = -7222.82739 MPa ---- 2 ---- angle 2 = 0 R+ = 7.9212116E-04 Sgm+ = 1188.18174 MPa R- = 1.13734025E-03 Sgm- = -1706.01038 MPa

Display	Operation	Print Out & Remarks
Buckling Y/N?	☐ Y ENTER	
Length & width in m?	☐ 1 ENTER	
Load N1, N2 in MN/m?	☐ 1 ENTER ☐ 0 ENTER	BUCKLING dim. of the plate (l, w, t) is (1, .1, 2E-03) load ratio (N2/N1) is 0 critical load .133719444 MN/m 0 MN/m mode 5,1 Load ratio is N2/N1. The dimension of the plate is: length, width, thickness. The buckling mode is given by mode i, j where i is the mode in length and j is the mode in width. The program restart to the first question. To study an other laminate strike key C1 (break) and F3 (RUN)
In plane calculations. Y/N?		

3. MEMORY CONTENT

MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
A	E_x				KB	calculation				A(6)	v_{61}^0, v_{61}^f			
B	E_y				KC					A(7)	v_{16}^0, v_{16}^f			
C	v_x				KD					A(8)	v_{62}^0, v_{62}^f			
D	E_s				KE					A(9)	v_{26}^0, v_{26}^f			
E	h_0				TT	control variable				B(1)	N^+			
F	$m=(1-v_x v_y)^{-1}$				XX	scale (10^a) factor				B(2)	N^-			
I	control variable				P	X				B(3)	σ^+			
J	"				Q	X'				B(4)	σ^-			
N	"				R	Y				T(1)	F_{xx}			
Z	"				S	Y'				T(2)	F_x			
CO	cosine θ				T	S				T(3)	F_{yy}			
SI	sine θ				U	calculation variable				T(4)	F_y			
TR	variable for trigonometric				A(1)	E_1^0, E_1^f				T(5)	F_{ss}			
TY	calculations				A(2)	E_2^0, E_2^f				T(6)	F_{xy}			
TX					A(3)	E_6^0, E_6^f				T(7)	G_{xy}			
TF					A(4)	v_{12}^0, v_{12}^f				T(8)	G_{yy}			
KA	constants for trigonometric				A(5)	v_{21}^0, v_{21}^f				T(9)	G_{xy}			

MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION			MEMORY	DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
W1	G_{ss}				B\$(6)	"26"				V(1)	invariants of the G_{ij} tensor			
W2	G_x				B\$(9)	"E1-"				V(2)	"			
W3	G_y				B\$(10)	"E2-"				V(3)	"			
E1	ϵ_1				B\$(11)	"E6-"				V(4)	"			
E2	ϵ_2				B\$(12)	"v21-"				V(5)	"			
E6	ϵ_6				B\$(13)	"v12-"								
V(I)	$A_{ij} D_{ij}$				B\$(14)	"v61-"								
Y(I)	angle of each ply				B\$(15)	"v16-"								
Z(I)	number of plies for each angle				B\$(16)	"v62-"								
X(I)	calculations variable				B\$(17)	"v26-"								
A\$(1)	"stiffness"				Z\$	output variable								
A\$(2)	"compliance"				G\$	"Y", "N"								
B\$(1)	"11"				U(1)	invariants of the Q_{ij} tensor								
B\$(2)	"22"				U(2)	"								
B\$(3)	"12"				U(3)	"								
B\$(4)	"66"				U(4)	"								
B\$(5)	"16"				U(5)	"								

4. SAMPLE PROBLEMS

C-1 T300/5208 $[0_1/90_1/\pm 45_1]_s$
 4 core plies

$$N_1 = 1 \text{ MN/m} \quad N_2 = N_6 = 0$$

$$M_1 = 1 \text{ N} \quad M_2 = M_6 = 0$$

C-2 T300/5208 $[0_4/90_4]_s$
 no core

$$N_1 = 1 \text{ MN/m} \quad N_2 = N_6 = 0$$

$$M_1 = 0, \quad M_2 = 1 \text{ N}, \quad M_6 = 0$$

$$M_1 = 1 \text{ N}, \quad M_2 = 0 \quad M_6 = 0, \quad M_1 = 1 \text{ MN}, \quad M_2 = 0, \quad M_6 = 0$$

C-3 Kevlar/Epoxy Sandwich $[\pm 30_4]_s$
 10 core ply

$$N_1 = 1 \text{ MN/m} \quad N_2 = N_6 = 0$$

$$M_2 = 1 \text{ MN} \quad M_2 = M_6 = 0$$

SAMPLE PROBLEM C-1

1 -T300/5208
2 -ALUMINIUM
3 -KEVLAR/EP
4 -GLASS/EPX

T300/5208

=====

ANGLE 1 = 0

number of Plies

= 1

=====

ANGLE 2 = 90

number of Plies

= 1

=====

ANGLE 3 = 45

number of Plies

= 1

=====

ANGLE 4 = -45

number of Plies

= 1

n. of core

Plies = 4

IN PLANE
CONSTANTS

STIFFNESS

in MN/m

A11 76.3682178

A22 76.3682176

A12 22.6073556

A66 26.8804311

A16 0

A26 0

COMPLIANCE

in 1/kN

a11 14.3521976

a22 14.3521976

a12 -4.24869459

a66 37.2017043

a16 0

a26 0

ENGINEERING
CONST.

E1-o 69.675 GPa

E2-o 69.675 GPa

E6-o 26.88 GPa

v21-o .296

v12-o .296

v61-o 0

v16-o 0

v62-o 0

v26-o 0

STIFFNESS

in GPa

A11 76.3682178

A22 76.3682176

A12 22.6073556

A66 26.8804311

A16 0

A26 0

COMPLIANCE

in TPa-1

a11 14.3521976

a22 14.3521976

a12 -4.2486946

a66 37.2017043

a16 0

a26 0

IN PLANE
STRENGTH

N1= 1 MN/m

N2= 0 MN/m

N6= 0 MN/m

===== 1 =====

angle 1 = -45

R+= .347657121

n+= 24

Sgm+=

S47.657121 MPa

R-= .677583674

n- = 10

Sgm- =

-677.583674 MPa

===== 2 =====

angle 2 = 45

R+= .347657122

n+= 24

Sgm+=

S47.657122 MPa

R-= .677583674

n- = 10

Sgm- =

-677.583673 MPa

===== 3 =====

angle 3 = 90

R+= .276743756

n+= 30

Sgm+=

276.743756 MPa

R-= 1.31149767

n- = 6

Sgm- =

-1311.49767 MPa

===== 4 =====

angle 4 = 0

R+= .58297431

n+= 14

Sgm+= 582.97431

MPa

R-= .566515812

n- = 14

Sgm- =

-566.515812 MPa

FLEXURAL
CONSTANTS

STIFFNESS

in Nm

D11 52.9323284

D22 43.5553373

D12 9.49191825

D66 11.9845457

D16 1.67446269

D26 1.67446273

COMPLIANCE

in (Nm)-1

d11 19.716124

d22 23.9937143

d12 -4.21341993

d66 34.1293669

d16 -2.16601447

d26 -2.76227587

ENGINEERING
CONST.

E1-f 76.879 GPa

E2-f 62.542 GPa

E6-f 17.829 GPa

v21-f .213

v12-f .175

v61-f -.11

v16-f -.026

v62-f -.116

v26-f -.033

STIFFNESS

in GPa

D11 79.3984926

D22 65.3330059

D12 14.2378774

D66 17.9768185

D16 2.51169403

D26 2.5116941

SAMPLE PROBLEM C-1 (Cont'd)

COMPLIANCE

in TPa-1
 d#11 13.1448826
 d#22 15.9891429
 d#12-2.88894662
 d#66 56.8862446
 d#16-1.44488964
 d#26-1.84151725

FLEXURAL
STRENGTH

M1= 1 MN
 M2= 0 MN
 M6= 0 MN

===== 1 =====

angle 1=-45

R+=
 4.12495439E-04

Sgm+=
 618.743159 MPa

R-=
 8.42675678E-04

Sgm- =
 -1264.81352 MPa

===== 2 =====

angle 2= 45

R+=
 3.24268165E-04

Sgm+=
 486.398249 MPa

R-=
 7.4321828E-04

Sgm- =
 -1114.81542 MPa

===== 3 =====

angle 3= 90

R+=
 2.28829112E-04

Sgm+=
 343.243669 MPa

R-=
 1.16682481E-03

Sgm- =
 -1750.23723 MPa

===== 4 =====

angle 4= 0

R+=
 4.84691727E-04

Sgm+=
 607.837591 MPa

R-=
 4.57858315E-04

Sgm- =
 -685.587474 MPa

BUCKLING

d.m. of the
 plate(1,u,t) 1

.1 2E-03
 load ratio

(N2/N1) is 0

critical load:
 .252981111 MN/m

0 MN/m

mode 5 . 1

SAMPLE PROBLEM C-2

1 -T300/5208
2 -ALUMINIUM
3 -KEVLAR/EP
4 -GLASS/EPX

T300/5208

ANGLE 1 = 0
number of plies
= 4

ANGLE 2 = 90
number of plies
= 4

n. of core
plies = 0

IN PLANE
CONSTANTS

STIFFNESS

in MN/m
A11 132.157298
A22 132.157298
A12 5.79394891
A66 14.34
A16 0
A26 0

COMPLIANCE

in mm²/N
a11 5.29880526
a22 5.29880528
a12-.157953784
a66 69.7250069
a16 0
a26 0

ENGINEERING
CONST.

E1=0 95.991 GPa
E2=0 95.991 GPa
E6=0 7.17 GPa
v21=0 .03
v12=0 .03
v61=0
v16=0
v62=0
v26=0

STIFFNESS

in GPa
A#11 96.0786488
A#22 96.0786488
A#12 2.39692445
A#66 7.17000001
A#16 0
A#26 0

COMPLIANCE

in TPa-1
a#11 10.4176106
a#22 10.4176106
a#12-.314107569
a#66 139.470014
a#16 0
a#26 0

IN PLANE
STRENGTH

N1= 1 MN/m
N2= 0 MN/m
N6= 0 MN/m
===== 1 =====
angle 1= 90
R+= .746808548
R+= 32
Sgm+=
673.404274 MPa
R-= 4.53828452
n= 2
Sgm=-
-2269.14226 MPa
===== 2 =====
angle 2= 0
R+= 1.36378965
R+= 12
Sgm+=
681.394823 MPa
R-= 2.21547627
n= 6
Sgm=-
-1107.73914 MPa

FLEXURAL
CONSTANTS

STIFFNESS

in N/m
I11 106.919678
I22 21.1861875
I12 1.93128297
I66 4.78000001
I16 0
I26 0

COMPLIANCE

in (Nm)-1
a11 9.26833561
a22 47.2734122
a12-.353994778
a66 209.225021
a16 0
a26 0

ENGINEERING
CONST.

E1=0 160.113
GPa
E2=0 31.726 GPa
E6=0 7.17 GPa
v21=0 .031
v12=0 .018
v61=0
v16=0
v62=0
v26=0

STIFFNESS

in GPa
D#11 160.378016
D#22 31.7792812
D#12 2.99692445
D#66 7.17000001
D#16 0
D#26 0

COMPLIANCE

in TPa-1
d#11 6.24555241
d#22 31.5139415
d#12-.569329852
d#66 139.470014
d#16 0
d#26 0

FLEXURAL
STRENGTH

N1= 0 MN
N2= 1E-06 MN
N6= 0 MN
===== 1 =====
angle 1= 90
R+= 318.180797
Sgm+= 477271197
MPa
R-= 555.029356
Sgm=-
-922544036 MPa
===== 2 =====
angle 2= 0
R+= 82.878661
Sgm+= 124317992
MPa
R-= 532.682322
Sgm=-
-729024235 MPa

FLEXURAL
STRENGTH

N1= 1 MN
N2= 0 MN
N6= 0 MN

SAMPLE PROBLEM C-2 (Cont'd)

```

===== 1 =====
angle 1= 90
R+=
8.35574406E-04
Sxx+=
1253.81161 MPa
R-=
4.81521825E-03
Sxx- =
-7222.32739 MPa
===== 2 =====
angle 2= 0
R+=
7.9212116E-04
Sxx+=
1188.18174 MPa
R-=
1.13734025E-03
Sxx- =
-1706.01038 MPa

```

FLEXURAL

STRENGTH

M1= 1E-06 MN

M2= 0 MN

M6= 0 MN

===== 1 =====

angle 1= 90

R+= 935.974403

S_{xx}+=

12538.116.1 MPa

R-= 4815.21825

S_{xx}- =

-72228273.9 MPa

===== 2 =====

angle 2= 0

R+= 792.12116

S_{xx}+=

11881817.4 MPa

R-= 1137.34025

S_{xx}- =

-17060103.8 MPa

BUCKLING

dim. of the

Plate(L, b, t) 1

.1 2E-03

load ratio

(N2/N1) is 0

critical loads:

.133719444 MN/m

0 MN/m

mode 5 , 1

SAMPLE PROBLEM C-3

1 - T300/5208
 2 - ALUMINIUM
 3 - KEVLAR/EP
 4 - GLASS/EPX
 KEVLAR/EP

 ANGLE 1 = 30
 number of Piles
 = 4

 ANGLE 2 = -30
 number of Piles
 = 4

n. of core
 Piles = 10

IN PLANE
 CONSTANTS

STIFFNESS

in MN/m
 A11 31.7789415
 A22 30.6841775
 A12 29.7375564
 A66 30.5560044
 A15 0
 A26 0

COMPLIANCE

in MN/m
 a11 30.395644
 a22 30.4543013
 a12 33.2985003
 a66 32.726792
 a15 0
 a26 0

ENGINEERING
 CONST.

E1-a 24.527 GPa
 E2-a 5.527 GPa
 E6-a 15.278 GPa
 v21-a 1.437
 v12-a .323
 v61-a 0
 v16-a 0
 v62-a 0
 v26-a 0

STIFFNESS

in GPa
 A#11 45.3894708
 A#22 10.3420887
 A#12 14.8637782
 A#66 15.2780022
 A#15 0
 A#26 0

COMPLIANCE

in MPa-1
 a#11 40.7712879
 a#22 180.908603
 a#12-58.5970007
 a#66 65.453584
 a#15 0
 a#26 0

IN PLANE
 STRENGTH

N1 = 1 MN/m
 N2 = 0 MN/m
 N6 = 0 MN/m
 ===== 1 =====
 angle 1 = -30
 R+ = .250398912
 n+ = 64
 Sgm+ =
 125.199456 MPa
 R- = .0990191266
 n- = 176
 Sgm- =
 -45.0095633 MPa

===== 2 =====
 angle 2 = 30
 R+ = .250398912
 n+ = 64
 Sgm+ =
 125.199456 MPa

R- = .0990191266
 n- = 176
 Sgm- =
 -45.0095633 MPa

FLEXURAL
 CONSTANTS

STIFFNESS
 in Nm
 I11 298.721254
 I22 55.0689752
 I12 92.5179382
 I66 96.1240974
 I16 40.0493119
 I26 13.824326

COMPLIANCE

in (Nm)-1
 d11 6.6690807
 d22 28.7603163
 d12-9.27804033
 d66 11.0438826
 d16-1.44427301
 d26-.270617426

ENGINEERING
 CONST.

E1-f 19.745 GPa
 E2-f 4.578 GPa
 E6-f 11.923 GPa
 v21-f 1.391
 v12-f .322
 v61-f-.217
 v16-f-.131
 v62-f-.01
 v26-f-.025

STIFFNESS

in GPa
 D#11 30.0209058
 D#22 3.56875392
 D#12 12.3151194
 D#66 12.6583173
 D#16 5.27398345
 D#26 1.82048737

COMPLIANCE

in MPa-1
 d#11 50.6433316
 d#22 218.398652
 d#12-79.4551188
 d#66 33.3644834
 d#16-10.9674482
 d#26-2.05500108

FLEXURAL
 STRENGTH

M1 = 1 MN
 M2 = 0 MN
 M6 = 0 MN
 ===== 1 =====
 angle 1 = -30
 R+ =
 4.5630055E-04
 Sgm+ =
 125.200163 MPa
 R- =
 1.49437463E-04
 Sgm- =
 -44.2777579 MPa
 ===== 2 =====
 angle 2 = 30
 R+ =
 3.44895089E-04
 Sgm+ =
 122.191137 MPa
 R- =
 1.3743141E-04
 Sgm- =
 -40.7204179 MPa

BUILDING
 diag. of the
 Plate (in m) 1
 .1 4.5E-02
 load ratio
 (N2/N1) is 0
 critical load:
 2.08863557 MN/m
 0 MN/m
 mode 5 1

4. PROGRAM LISTING

The program, when running, utilizes the whole 8k RAM (1117 bytes free before running, only two bytes free when running).

The program has two subroutines to perform trigonometric functions (SINE & COSINE). This part could be skipped by using the scientific ROM which could be attached on the hand-held computer. This ROM was not available at the time when we made the program.

The program can be saved on a programmable external memory, to transfer the software on other computers. No cassette or disc interface is built in the hand-held computers.

PROGRAM LISTING

```

5 ATTACH 66 TO
#2
10 INPUT "1-LOD
37
2-Printer"IC
30 DIM
#13) (9) Z(9)
V(12) AS(2) A(
9) B(4) B$(17)
NM(3)
34 DATA
"11" "22" "12"
"66" "16" "36"
"77" "E1-" "E3
-" "E6-" "v21-"
"v12-"
36 DATA
"v61-" "w16-"
"v62-" "w26-"
100 DATA
"1300/5200" .131
E3 .40.3E3 .128.7
.1TE3 .125E-3.1
500.1500.40.246
.68
200 DATA
"ALUMINIUM" .69E
3.69E3 .3.26.5E
3.1.400.400.400
.400.230
300 DATA
"KEVLAR/EP" .76E
3.5.5E3 .34.2.3
E3 .125E-3.1400
.205.12.53.34
400 DATA
"GLASS/EPX" .38.
6E3 .8.27E3 .126.
4.14E3 .125E-3.
1026.610.31.118
.72
1900 INPUT
"MATRIAL n for
menu"IG$
1810 RESTORE
:FOR I=1 TO
17:READ
B$(I):NEXT I
1820 N= VAL
(IG$):IF
G$="n" THEN N=4
1825 FOR I=1 TO
N:READ
A$(I).A.B.C.D.
P.Q.R.S.T
1830 IF
G$="n" THEN
PRINT
*Z11: "-":A$(0)
1835 NEXT I:IF
G$="n" THEN
GOTO 1850

```

```

1848 GOTO 1900
1850 PRINT
*Z:AS(O)
2000
AS(1)="STIFFNES
3":AS(2)="COMPL
IANCE"
2100 INPUT "No
of angles" IG
2300
F=1/1-C#C#B/A)
X1=F#A:X2=F#B:
X3=F#C#B:X4=D
2310
U1=(3#X1+3#X2+2
#X3+4#X4)/8
2320
U2=(X1-X2)/2
2330
U3=(X1+X2-2#X3-
4#X4)/8
2340
U4=(X1+X2+6#X3-
4#X4)/8
2350
U5=(X1+X2-2#X3+
4#X4)/8
2355
T1=1/P/Q:T2=1/P
-1/Q:T3=1/R/S:T
4=1/P-1/S:T5=1/
T1+T3:T6=1/2
2360 T6-T6=SQR
(T1#T3)
2380
T7=T1#X1^2+2#T6
#X1#X3+T3#X3^2
2390
T8=T1#X3^2+2#T6
#X3#X2+T3#X2^2
2400
T9=T1#X1#X3+T6#
(X1#X2+X3^2)+T3
#X3#X2
2405
W1=T5#X4^2:W2=T
3#T1+T4#X3:W3=T
2#X3+T4#X2
2410
V1=(3#T7+3#T8+2
#T9+4#W1)/8:V2=
(T7-T8)/2
2430
V3=(T7+T9-2#T9-
4#W1)/8:V4=(T7+
T8-6#T9-4#W1)/8
2450
V5=(T7+T8-2#T9-
4#W1)/8
2920 FOR I=1 TO
IG
2940 INPUT
"angle="
"V/(G-I+1)

```

```

2950
H$="ANGLE"+STR$(
(1)+""="
2960 IF Z=Z
THEN PRINT
#Z:*****
*
2970 PRINT
#Z:H$Y(G-I+1)
2980 INPUT "No
of Piles
=" :ZIG-I+1
2990 PRINT
#Z:"number of
Piles
=" :ZIG-I+1
3000 NEXT I
3100 INPUT "No
of core
Piles=" :LZXZ
:"ZIG"
3200 PRINT
#Z:"n. of core
Piles=" :ZIG
3400 INPUT "n
of line
calculation
=" :n'IG$
3500 #S$="IN
PLANE
CONSTANTS"
3600 GOSUB 6000
3700 FOR I=1 TO
Z:GOSUB 7000
3710
U=2*G(I)*#E*(X+10
)=*(X+10)+U
3720 FOR J=1 TO
G(I):GJ=U*(J)+U*(X
(J):NEXT J:NEXT
I
3750
IS$="A":IN=1:TT=0
:XX=1:US$="N/A"
:IF IS$="Y" THEN
GOSUB 3900
3770 GOTO 5400
3800 GOSUB
51000:PRINT
#Z:XS,ASIN(XS/US
):US
3900 FOR I=1 TO
G-I+1:IF ABS
(V(I)-TT)*XX<1E
-4 THEN LET TT=V(I)
4000 PRINT
#Z:IS+BS$ :V(I)
:TT:XX:GJ:NEXT
I:RETURN
4070
US$="GP":GOSUB
51300:PRINT
#Z:"ENGINEERING
CONST. :GP:PRINT
#Z

```

PROGRAM LISTING (Cont'd)

```

5000 FOR I=1 TO
  5:XX=1E-3:IF
  >3 THEN LET
  XX=1:US=""
5050 IF ABS
  A(1)<1E-6
  THEN LET A(1)=0
5100 PRINT
  *2:3$(I+8)+Z$:1
  E-5*INT
  (1E3*A(I)*XX):U
  S
5150 NEXT
  I:RETURN
5400 GOSUB
  3000:XS="":Z$="
  a":N=2:TT=6:XX=
  1E3:US="m/kN":1
  F:G$="y" THEN
  GOSUB 3800
5300 GOSUB
  12000
5900
  Z$="o":INPUT
  "engin.
  const.-3/n
  G$:IF
  G$="x" THEN
  GOSUB 4970
6000 INPUT
  "norm.
  const.3/n":G$
6050
  Z$="a":N=1:TT=
  0:XX=1E-3:US="G
  P:"
6060 IF
  G$="y" THEN
  GOSUB
  12300:GOSUB
  3800
6150
  Z$="a":N=2:TT=
  6:XX=1E6:US="TP
  a-1":IF
  G$="y" THEN
  GOSUB
  3800:GOSUB
  12400
6200 GOTO 13000
6200 FOR I=1 TO
  5:V(I)=0:NEXT
  I:RETURN
7000 GOSUB
  50000:TX=2*V(I)
  :GOSUB
  50100:S2=TR:GOS
  UB 50120:C2=TR
  7010
  TR=4*V(I):GOSUB
  50100:S4=TR:GOS
  UB 50120:C4=TR

```

```

7100
  X(1)=U1+C2*U2+C
  4*U3
7200
  X(2)=U1-C2*U2+C
  4*U3
7300
  X(3)=U4-C4*U3
7400
  X(4)=U5-C4*U3
7500
  X(5)=S2*U2/2+S4
  *U3
7600
  X(6)=S2*U2/2-S4
  *U3:RETURN
8000
  DT=V(1)*V(2)*V(
  4)+2*V(3)*V(6)*
  V(5)-V(2)*V(5)*
  2-V(1)*V(6)*2-V
  4*V(3)*2
8200
  V(7)=(V(2)*V(4)
  -V(6)*2)/DT
8250
  V(8)=(V(1)*V(4)
  -V(5)*2)/DT
8300
  V(9)=(V(5)*V(6)
  -V(3)*V(4))/DT
8400
  V(10)=(V(1)*V(2)
  -V(3)*2)/DT
8500
  V(11)=(V(3)*V(6)
  -V(2)*V(5))/DT
8600
  V(12)=(V(2)*V(5)
  -V(1)*V(6))/DT
:RETURN
12000
  A(1)=1/X(10)/V(
  7):A(2)=1/X(10)
  :V(3):A(3)=1/X(
  10)/V(10)
12100
  A(4)=-V(9)/V(7)
  :A(5)=-V(9)/V(8)
  :A(6)=V(11)/V(
  7)
12200
  A(7)=V(11)/V(10)
  :A(8)=V(12)/V(
  9):A(9)=V(12)/V
  (10):RETURN
12300 FOR J=1
  TO
  6:V(J)=V(J)*X(1
  0):V(J+6)=V(J+6
  )*X(10):NEXT
  J:RETURN

```

```

12400 FOR J=1
  TO
  5:V(J)=V(J)*X(1
  0):V(J+6)=V(J+6
  )*X(10):NEXT
  J:RETURN
12000 INPUT
  "air length
  -> n":G$:IF
  G$="x" GOTO
  27000
12200 GOSUB
  51000:PRINT
  *2:PRINT *2:"IN
  PLANE
  STRENGTH":PRINT
  *2
12400
  Z$="N":US="mm/m
  ":GOSUB
  12900:GOSUB
  14200:GOTO
  14500
12900 FOR I=1:
  TO
  10:G$=Z$+MID$*B
  *I-2:3:1)+1E-
  4:PRINT
  G$+" "+US+" "
12950 INPUT
  NM:I=10:PRINT
  *2:G$:NM:I=10:1
  US:NEXT
  I:RETURN
14200
  E1=V(7)*NM(1)+V
  (9)*NM(2)+V(11
  )*NM(3)
14300
  E2=V(9)*NM(1)+V
  (3)*NM(2)+V(12
  )*NM(3)
14400
  E3=V(11)*NM(1)+
  V(12)*NM(2)+V(1
  3)*NM(3):RETURN
14500 FOR I=1
  TO
  5:G$="angle"-ST
  R$*I+"="
15000 GOSUB
  15500:NEXT
  I:GOTO 27000
15500 GOSUB
  50000:TX=2*V(I)
  :GOSUB
  50100:S2=TR:GOS
  UB 50120:C2=TR
  15550
  TX=4*V(I):GOSUB
  50100:S4=TR:GOS
  UB 50120:C4=TR

```

PROGRAM LISTING (Cont'd)

```

15600
G1=V1+C2*V2+C4*
V3
15650
G2=V1-2*V2+C4*V
3
15700
G3=V4-C4*V3
15750
G4=V5-C4*V3
15800
G6=S2*V2/2-14*V
3
15900
J1=-w2+w3+0.1e+
3-w3/11 B=0.3=w2
+w3-0.2*(w2-w3)/
/21 C=0.2*(w2-w3
)/21
16000
A=G1+E1*2+G2+E2
*2-G4+E6*2+2*(G
2+E1+E2+G5+E1+E
6+G6+E2+E6)
16100
B=J1+E1+J2+E2+J
3+E6
16200
R1=(-B+SQP
(B*B+4*A))/2/A
16300
R2=(-B-SQP
(B*B+4*A))/2/A
16400 B(1)=INT
((10)/E/R1/2+1
)*2
16450 B(2)=INT
((10)/E/R2/2+1
)*2
16470
B(3)=R1/X(10):B
(4)=R2/X(10)
16520 PRINT
#Z:"====":I:"
===="
16530 PRINT
#Z:H$;Y(I)
16550 PRINT
#Z:"R+":R1
16560 IF A(1)<1
THEN 16650
16600 PRINT
#Z:"r+":B(1)
16650 PRINT
#Z:"Sgm+":B(3)
:"MPa"
16700 PRINT
#Z:"R-+":ABS
(R2)
16730 IF A(1)<1
THEN 16800
16750 PRINT
#Z:"n-+":ABS
(B/2)

```

```

16800 PRINT
#Z:"Sgm- ="
:"(4)":MPa":RE
TURN
17000 INPUT
"flex.
calculations
-y/n":G$:X$="FL
EXURAL
CONSTANTS"
17400 GOSUB
1800:X(10)=Z(0)
*E
17700 FOR I=1
TO 5:GOSUB 7000
17850
X(10)=X(10)+E*Z
(I)
17900
I=2/3*(X(10)+3-
(X(10)-Z(I)*E)*
3)
18000 FOR J=1
TO
S:V(J)=V(J)+U*X
(I):NEXT J:NEXT
I:UU=X(10)
18500
N=1:Z$="D":TT=0
:XX=1E-3:US="Nm"
:IF G$="Y"THEN
GOSUB 3800
19100 GOSUB
3000
19300
V$="":N=2:Z$="d
":TT=6:XX=1E-3:
J$="(Nm)-1":IF
Z$="Y"THEN
GOSUB 3800
19400
X(10)=2*X(10)+3
*3:GOSUB 12000
19600 INPUT
"eng.
const.":G$:Z$="
"
19700 IF
Z$="Y"THEN
GOSUB 4970
19800 INPUT
"norm.
const.":G$
30100
Z$="J":N=1:TT=
0:XX=1E-3:US="G
Pa":IF
G$="Y"THEN
GOSUB
12300:GOSUB
2900
30500
Z$="d":N=2:TT=
0:XX=1E6:US="TP
a-1":IF
G$="Y"THEN

```

```

GOSUB
3800:GOSUB
13400
13900 INPUT
"strength y/n
":G$:IF
G$="Y"GOTO
30100
31200 GOSUB
51050:PRINT
#Z:"FLEXURAL
STRENGTH"
31500
Z$="M":US="MN":
GOSUB 13900
32300
+0)=Z(10)*E:
2)=X(10)*E*1.1
2-3)/6
32400 FOR I=1
TO
S:A(I)=A(I-1)+
(I)*E:H$="angl-
+STR$(I)+"=":G
OSUB 14200
32500
E1=E1*A(I):E2=E
2*A(I):E6=E6*A
(I):GOSUB
15500:NEXT I
33100 INPUT
"BUCKLING
y/n":G$:IF
G$="Y"THEN
GOTO 3400
33110 GOSUB
40000:GOTO 3400
40000 GOSUB
51000:PRINT
#Z:"BUCKLING":T
V=1E33
40010 INPUT
"length & width
in m":B,C:INPUT
"LOAD N1/N2 in
MN/m":K,L
40025 PRINT
#Z:"dim. of the
plate(L,W,t)
":B/C:2*UU:"load
ratio N2/N1
is:L/K
40040 FOR I=1
TO 5:FOR J=1 TO
5:D=(1/B)^2+(J/
C)^2*L/K
40050
TV=4*U^2*B*((1/
B)-4*U/1-2*(V/
3)-2*U/4)+*1*J
/8/C+2+V(C)*(J
/C)^4)
40060 IF TV>TY
THEN 40065

```

```

40065
TV=TX*M/I:N=J
40065 NEXT
J:NEXT I
40070 PRINT
#Z:"critical
load":TV:PRINT
"mode":M:I:TV
:RETURN
50000
F=2E-16:A=1.576
79633:B=INT
(3.1415926535897
16):C=3.1415926
535897
50070
H=-.156666666666
=.156666666666
=.156666666666
50080
S0390
J=-.135400333333
34K=.2752227111
53L=-.1352666666
4E-7:RETURN
50100
TV=TV*3.1415926
51100:TV=ABS
(TV):TV=SGN
(TV):GOTO 50150
50120 TV=ABS
(TV)+4:TV=1/50
150150
50150 IF TV=0
THEN PRINT
"error:STOP
50160 TN=INT
(TV)+.5
50170
TT=.5*TN:IF TT
INT(TT)THEN
TV=TV
50180 IF ABS
(TV) < TN THEN
TV=TN+.5
50190 TR=ABS
(TV)-TN+TN+INOW
50200 IF ABS
(TV) < TN THEN
TR=TR:GOTO
50230
50220
TR=TR+2:TV=
L+TR+K*TP+J*
R+M)*TP+M*TP
50230
TR=TR+TR*TP:IF
TV=0 THEN
TR=-TV
50240 RETURN
51000 IF Z=1
THEN RETURN
51050 PRINT
#Z:"
-":RETURN

```

SECTION IV

CONCLUSIONS

The description and the instructions for the use of the Panasonic HR-1800 Hand-Held Computer, the calculations of the stiffness and strength of symmetric laminates, are presented in this report. This package has been made very easy to use and requires no previous knowledge. Instant calculations can be made for practical use.

END

FILMED

5-84

DTIC