AD-A130 421 SHARP PC-1500 POCKET COMPUTER SOLUTIONS TO COMPOSITE MATERIALS FORMULAS(U) UNIVERSAL ENERGY SYSTEMS INC DAYTON OH W J PARK ET AL. DEC 82 AFWAL-TR-83-4016 1/1

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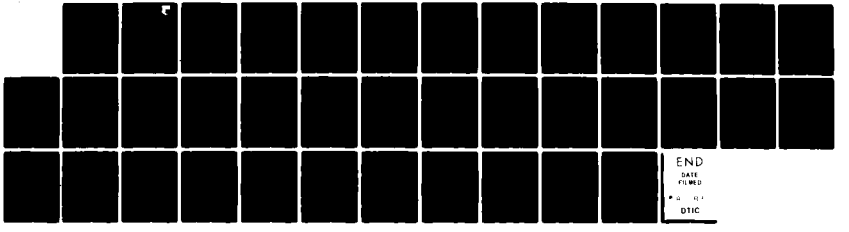

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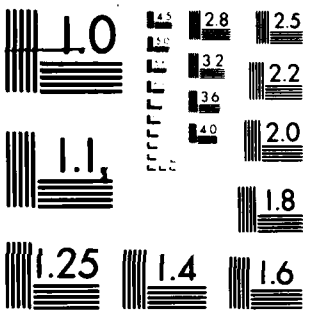

AFWAL-TR-83-4016

SHARP PC-1500 POCKET COMPUTER SOLUTIONS TO COMPOSITE MATERIALS FORMULAS

WON J. PARK
UNIVERSAL ENERGY SYSTEMS, INC.
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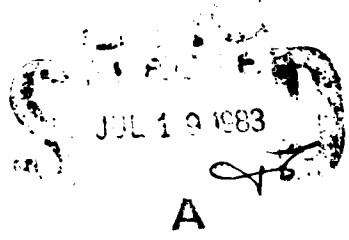
DECEMBER 1982

FINAL REPORT FOR PERIOD JUNE 1982-DECEMBER 1982

MATERIAL LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AFB, OHIO 45433



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This report has been reviewed by the Office of Public Affairs (ASD/PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

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

S.W. TSAI, Project Engineer & Chief
Mechanics and Surface Interactions Branch
Nonmetallic Materials Division

FOR THE COMMANDER

F.D. CHERRY, Chief
Nonmetallic Materials Division

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16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

These programs use the language of BASIC and with additional 8KB RAM memories. The computer software contained in this report is theoretical and/or references and in no way relfect Air Force-owned or developed computer software.

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

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This volume contains the description and instructions of the use of Sharp PC-1500 Pocket 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 from a book entitled, Introduction to Composite Materials, co-authored by S. W. Tsai and H. T. Hahn, published by Technomic Publishing Company, Westport, CT, July 1980.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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. The work was performed under Contract F33615-82-C-5001; SB5448-82-C-0086.

The time period covered by this report was from June to December 1982. Dr. Won J. Park was a senior scientist from Universal Energy Systems, Inc. and Professor of Mathematics and Statistics at Wright State University.

Dr. Thierry N. Massard was a visiting scientist at Materials Laboratory, Air Force Aeronautical Laboratories, Wright-Patterson AFB, Dayton, Ohio, and a Chief engineer at the Commissariat L'Energie Atomique, Montrouge, France.

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, CT, in July 1980.

Those who want to receive the programmed magnetic cassette tape should contact Stephen W. Tsai, AFWAL/MLBM, Wright-Patterson AFB, Dayton, Ohio 45433, Tel: 513-255-3068.

TABLE OF CONTENTS

SECTION I

USER GENERAL INSTRUCTIONS

(1) The program language for PC-1500 Pocket Computer is BASIC and the elementary part of BASIC program instructions are given in the SHARP Intruction manual, which comes with PC-1500 Pocket Computer.

(2) The 8 K RAM should be attached to the computer to increase its capacity. Printer is necessary for Version 1 and 2. If not available, choose Version 3 of the program.

(3) The programs are called SYM-LAM 1, SYM-LAM 2, and SYM-LAM 3. They are three different displays of the same calculation:

SYM-LAM 1 (Version 1) gives vertical printing on the paper,

SYM-LAM 2 (Version 2) gives horizontal printing with matrix form on the paper,

SYM-LAM 3 (Version 3) gives results on the display window and does not require the printer.

The programs are started in mode RUN by instruction RUN (press the keys [R] [U] [N] and [ENTER]). User is guided through the programs by simple questions. The user types the chosen answer and presses the key [ENTER] .

(4) The programs are recorded on a magnetic cassette with tape counter readings:

SYM-LAM 1 : 0 - 200

SYM-LAM 2 : 250 - 400

SYM-LAM 3 : 450 - 540

Instruction CLOAD "SYM-LAM 1" ("SYM-LAM 2" or "SYM-LAM 3") is used to load the program from the cassette recorder to the computer.

(5) The program considers only symmetric laminates of composite materials.

SECTION II

CONTENTS OF PROGRAMS

The program performs specific operations and computations of composite materials:

(1) Description of the laminates.
- number of angles
- number of plies for each angle
- number of core plies (for flexural stiffness of sandwich plate only)

(2) In-plane stiffness of symmetric laminates.
- modulus and compliance

(3) Engineering constants.

(4) Normalized in-plane stiffness.
- modulus and compliance

(5) In-plane strength.

(6) Stress failure enevelope.

(7) Strain failure enevelope.

(8) Flexural rigidity of symmetric sandwich plates.
- modulus and compliance

(9) Flexural strength of symmetric sandwich plates.

REMARKS:

(a) The materials constants are stored in the program. When

REMARKS: (cont'd)

"MATERIAL N. =" is asked, input the material number or press M, which gives the menu for materials numbers:

1 - T300/5208

2 - B(4)/5505

3 - AS-3501

4 - Schotchply/1002

5 - Kevlar 49/Epoxy

To add other materials (up to 10), user should type (in PRO mode) for a material N. = x: (line 10 * x)

10 * x: DATA "Name of Material", E_x, E_y, ν_x, E_s, h_o, X, X', Y, Y', S: RETURN

An example of adding a new material (Aluminum-material number 6) is as follows:

Set PRO mode, write 60 DATA "ALUMINUM", 69E3, 69E3, .3, 26.5E3, .125E-3, 400, 400, 400, 230: RETURN and press ENTER .

The unit of engineering constants are in MPa and thickness is in meter.

(Do not forget to save the modified program on the cassette tape using instruction CSAVE "SYM-LAM1" ("SYM-LAM2" or "SYM-LAM3"). The menu is set automatically up to date.

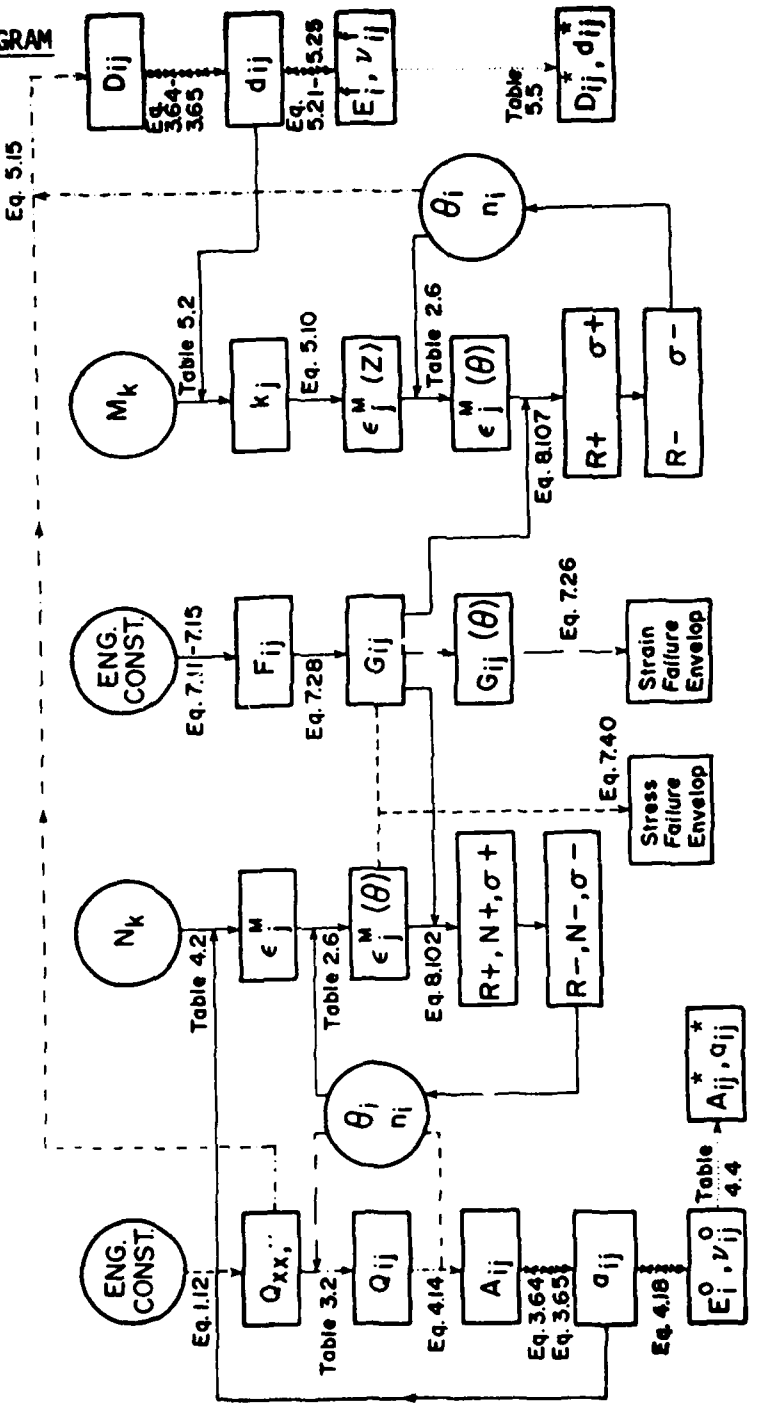
(b) The order of angles to be entered starts from the angle closer to the mid-plane. This is very important in the flexural rigidity and strength computations.

(c) The value of F^*_{xy} was programmed as $0 = -\frac{1}{2}$ in the program step 1025. For $F^*_{xy} \neq -\frac{1}{2}$, the new value should be entered directly in the program at this step (mode PRO).

SECTION III

PROGRAM DESCRIPTION

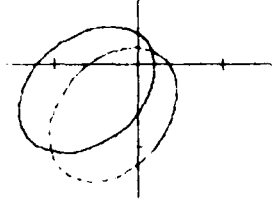
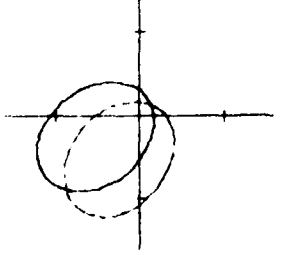
(A) FLOW DIAGRAM



(B) KEY OPERATION PROCEDURE (T300/5208, $[0_4/90_4]_s$ and version 1)

DISPLAY & OPERATION	PRINT OUT & REMARKS
R U N ENTER	
COLOR (0,1,2,3) 0 ENTER	Color Numbers 0 - black 2 - green 1 - blue 3 - red
MATERIAL N. = (M for MENU)? M ENTER	Menu for Materials
MATERIAL N. = (M for MENU)? 1 ENTER	T300/5208
DEFINE THE LAMINATE HOW MANY ANGLES 2 ENTER ANGLE = 90 ENTER NO. OF PLIES 4 ENTER ANGLE = 0 ENTER NO. OF PLIES 4 ENTER N. OF CORE PLIES 0 ENTER	ANGLE 1 = 90 NO.OF PLIES = 4 ANGLE 2 = 0 NO.OF PLIES = 4 N.OF CORE PLIES 0
IN-PLANE STIFFNESS - Y/N? Y ENTER	IN PLANE STIFFNE MODULUS A11 192.157MN/m A22 192.157MN/m A12 5.793MN/m A66 14.340MN/m A16 0.000MN/m A26 0.000MN/m COMPLIANCE a11 5.208m/kN a22 5.208m/kN a12 -0.157m/kN a66 69.735m/kN a16 0.000m/kN a26 0.000m/kN

DISPLAY & OPERATION	PRINT OUT & REMARKS
ENGINEERING CST Y ENTER	- Y/N? E1-o 95.991GPa E2-o 95.991GPa E6-o 7.170GPa ν21o 0.030 ν12o 0.030 ν61o 0.000 ν16o 0.000 ν62o 0.000 ν26o 0.000
NORMALIZED CST Y ENTER	- Y/N? NORMALIZED CONST MODULUS A11* 96.078GPa A22* 96.078GPa A12* 2.896GPa A66* 7.170GPa A16* 0.000GPa A26* 0.000GPa INV. MAT.(TPa)-1 COMPLIANCE a11* 10.417 a22* 10.417 a12* -0.314 a66* 139.470 a16* 0.000 a26* 0.000
IN-PLANE STRENGTH - Y/N? Y ENTER N1 = (MN/m) ENTER ? 1 ENTER N2 = ENTER 0 ENTER N6 = ENTER 0 ENTER	N1 = 1.000MN/m N2 = 0.000MN/m N6 = 0.000MN/m ANGLE 1 = 90 R = .327 N = 22.000 Sam = 423.390MPa R = 4.432 N = 4.000 Sam = 2268.818MPa ANGLE 2 = 0 R = .303 N = 12.000 Sam = 681.834MPa R = 2.214 N = 8.100 Sam = 1102.345MPa

DISPLAY & OPERATION	PRINT OUT & REMARKS
FAIL. ENV. IN STRESS - Y/N? Y ENTER ANGLE NO. is= 1 ENTER COLOR NO. is= 0 ENTER ANGLE NO. is= 2 ENTER COLOR NO. is= 2 ENTER ANGLE NO. is=(*) 5 ENTER NEW SCALE - Y/N? Y ENTER W = ? 1 6 ENTER	(*)Entering an angle number greater than the number of angles on the laminate terminates the graphic operation
ANGLE NO. is= 1 ENTER COLOR NO. is= 0 ENTER ANGLE NO. is= 2 ENTER COLOR NO. is= 2 ENTER ANGLE NO. is= 5 ENTER NEW SCALE? N ENTER FAIL. ENV. IN STRAIN - Y/N? Y ENTER ANGLE NO. IS = 1 ENTER COLOR NO. IS = 0 ENTER ANGLE NO. IS = 2 ENTER	1875.0MPa  STRAIN SPACE 0.020222 

DISPLAY & OPERATION	PRINT OUT & REMARKS
COLOR NO. IS = 2 ENTER ANGLE NO. IS = 5 ENTER NEW SCALE - Y/N? N ENTER	
FLEXURAL STIFFNESS - Y/N? Y ENTER	FLEX. STIFFNESS MODULUS D11 106.918N.m D22 21.186N.m D12 1.931N.m D66 4.780N.m D16 0.000N.m D26 0.000N.m INV.MAT.(kN.m)-1 COMPLIANCE d11 9.368 d22 47.228 d12 -0.853 d66 209.205 d16 0.000 d26 0.000
ENGIN. FLEX. CST - Y/N? Y ENTER	E1-f 160.113GPa E2-f 31.726GPa E6-f 7.169GPa ν21f 0.091 ν12f 0.018 ν61f 0.000 ν16f 0.000 ν62f 0.000 ν26f 0.000
NORM. FLEX. CST. - Y/N? Y ENTER	NORMALIZED CONST MODULUS D11* 160.378GPa D22* 31.779GPa D12* 2.896GPa D66* 7.170GPa D16* 0.000GPa D26* 0.000GPa INV. MAT.(TPa)-1 COMPLIANCE d11* 6.245 d22* 31.518 d12* -0.569 d66* 139.420 d16* 0.000 d26* 0.000

DISPLAY & OPERATION	PRINT OUT & REMARKS	DISPLAY & OPERATION	PRINT OUT & REMARKS
FLEXURAL STRENGTH - Y/N? Y ENTER M1 = ENTER 1 ENTER M2 = ENTER 0 ENTER M6 = ENTER 0 ENTER	M1 = 1.000MN M2 = 0.000MN M6 = 0.000MN ANGLE 1 = 90 R+ = 0.000 Sgm+= 1253.541MPa R- = 0.004 Sgm-= 7213.872MPa		ANGLE 2 = 0 R+ = 0.000 Sgm+= 1187.969MPa R- = 0.001 Sgm-= 1705.573MPa
		At the end of the program it starts again to IN-PLANE STIFFNESS. To end or stop the program, press the key ON ("break")	

(C) MEMORY CONTENTS

Memory	DESCRIPTION	VERSION 1	2	3	Memory	DESCIPRTION	VERSION 1	2	3	Memory	DESCRIPTION	VERSION 1	2	3
A	E_x				S	Y'				A(2)	E_2^o E_2^f			
B	E_y				T	S				A(3)	E_6^o E_6^f			
C	ν_x				U	x_o				A(4)	ν_{21}^o ν_{21}^f			
D	E_s				V	y_o				A(5)	ν_{12}^o " ν_{12}^f			
F	$m=(1-\nu_x\nu_y)^{-1}$				W	scale factor			x	A(6)	ν_{61}^o " ν_{61}^f			
G	k = number of Angles				X	x				A(7)	ν_{16}^o " ν_{16}^f			
H	*				Y	y				A(8)	ν_{62}^o " ν_{62}^f			
I	*				Z	*				A(9)	ν_{26}^o ν_{26}^f			
J	*				AA	**				B(1)	N+			
K	N_1 M_1				BB	**				B(2)	N-			
L	N_2 M_2				CC	**			x	B(3)	σ+			
M	N_6 M_6				II	*	x		x	B(4)	σ-			
N	*				LL	**	x		x	B(10)	H_{11}			
O	F^*_{xy}				PP	**	x		x	B(20)	H_{12}			
P	X				TT	*				B(21)	H_{22}			
Q	X'				XX	*				B(23)	H_1			
R	Y				A(1)	E_1^o E_i^f				B(24)	H_2			

Memory	DESCRIPTION	VERSION 1	2	3	Memory	DESCRIPTION	VERSION 1	2	3	Memory	DESCRIPTION	VERSION 1	2	3
U(1)	F_{xx}				U(21)	G_{12}				V(16)	A^*_{66} D^*_{66}			
U(2)	F_x				U(22)	G_{66}				V(17)	A^*_{16} D^*_{16}			
U(3)	F_{yy}				U(23)	G_1				V(18)	A^*_{26} D^*_{26}			
U(4)	F_y				U(24)	G_2				V(19)	a^*_{11} d^*_{11}			
U(5)	F_{ss}				V(1)	A_{11} D_{11}				V(20)	a^*_{22} d^*_{22}			
U(6)	F_{xy}				V(2)	A_{22} D_{22}				V(21)	a^*_{12} d^*_{12}			
U(7)	G_{xx}				V(3)	A_{12} D_{12}				V(22)	a^*_{66} d^*_{66}			
U(8)	G_{yy}				V(4)	A_{66} D_{66}				V(23)	a^*_{16} d^*_{16}			
U(9)	G_{xy}				V(5)	A_{16} D_{16}				V(24)	a^*_{26} d^*_{26}			
U(10)	G_{ss}				V(6)	A_{26} D_{26}				V(25) |	graphic variables			x
U(11)	G_x				V(7)	a_{11} d_{11}				V(31)				x
U(12)	G_y				V(8)	a_{22} d_{22}				X(1)	Q_{xx}			
U(13)					V(9)	a_{12} d_{12}				X(2)	Q_{yy}			
U(14)	A'				V(10)	a_{66} d_{66}				X(3)	Q_{xy}			
U(15)	B'				V(11)	a_{16} d_{16}				X(4)	Q_{ss}			
U(16)	D' R+				V(12)	a_{26} d_{26}				X(5)	m^4			
U(17)	E' R-				V(13)	A^*_{11} D^*_{11}				X(6)	m^3n			
U(19)	G_{11}				V(14)	A^*_{22} D^*_{22}				X(7)	m^2n^2			
U(20)	G_{22}				V(15)	A^*_{12} D^*_{12}				X(8)	mn^3			

	DESCRIPTION	VERSION				DESCRIPTION	VERSION				DESCRIPTION	VERSION		
		1	2	3			1	2	3			1	2	3
X(9)	n^4				Y(I)	θ_i				L$	"ν_{12}"			
X(10)	h, $\frac{h^2}{6}$, $\frac{h^3}{12}$				Z(I)	n_i				M$	"ν_{21}"			
X(11)	Q_{ij}				A$	"11"				N$	"ν_{16}"			
X(16)					B$	"22"				O$	"ν_{61}"			
X(17)	ε_1^0 k_1				C$	"12"				P$	"ν_{26}"			
X(18)	ε_2^0 k_2				D$	"66"				Q$	"ν_{62}"			
X(19)	ε_6^0 k_6				E$	"16"				T$(1)	" "			
X(20)	ε_x				F$	"26"				T$(2)	" * "			
X(21)	ε_y				G$	Y/N				AA$(1)	"MODULUS"			
X(22)	ε_s				H$	ANGLE				AA$(2)	"COMPLIANCE"			
X(23)	m^2				I$	"E1-"				W$	"MATERIAL"			
X(24)	n^2				J$	"E2-"				C(I,J)	MATRIX ENTRY VARIABLES	x		x
X(25)	mn				K$	"E6-"				E	h_o			
X(26)	X(1)													
X(29)	X(4)													

* Control variable

** - Formate or Printing variable

x - memory is not applicable

α = rotation angle for ellipse

A' - E = Coefficient of elliptic equation rotated

(D) SAMPLE PROBLEMS

1. T300/5208, $[0_2/90_2/\pm 45_2]_s$ (Version 1)

2. T300/5208, $[0_4/90_4]_s$ (Version 2)

3. T300/5208, $[0/90/\pm 45/CORE_4]_s$ (Version 1)

1. T300/5208, $[0_2/90_2/\pm 45_2]_s$ (Version 1)

T300/5208

ANGLE 1 = 45
NO.OF PLIES = 2
ANGLE 2 = 45
NO.OF PLIES = 2
ANGLE 3 = 90
NO.OF PLIES = 2
ANGLE 4 = 0
NO.OF PLIES = 2
N.OF CORE PLIES 0

IN PLANE STIFFNE
MODULUS

A11	152.736MN/m
A22	152.736MN/m
A12	45.214MN/m
A66	53.760MN/m
A16	0.000MN/m
A26	0.000MN/m

COMPLIANCE

a11	7.126m/kN
a22	7.126m/kN
a12	-2.124m/kN
a66	18.600m/kN
a16	0.000m/kN
a26	0.000m/kN

E1-o	69.675GPa
E2-o	69.675GPa
E6-o	26.880GPa
ν21o	0.296
ν12o	0.296
ν61o	0.000
ν16o	0.000
ν62o	0.000
ν26o	0.000

NORMALIZED CONST
MODULUS

A11*	76.368GPa
A22*	76.368GPa
A12*	22.607GPa
A66*	26.880GPa
A16*	0.000GPa
A26*	0.000GPa

INV. MAT.(TPa)-1
COMPLIANCE

a11*	14.352
a22*	14.352
a12*	-4.248
a66*	37.201
a16*	0.000
a26*	0.000

N1 =	1.000MN/m
N2 =	0.000MN/m
N6 =	0.000MN/m

ANGLE 1 = 45
R+ = 0.693
N+ = 24.000
Sgm+ = 646.995MPa

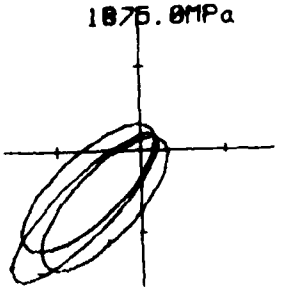
R- = 1.350
N- = 12.000
Sgm- = 625.075MPa

ANGLE 2 = 45
R+ = 0.693
N+ = 24.000
Sgm+ = 646.995MPa
R- = 1.350
N- = 12.000
Sgm- = 625.075MPa

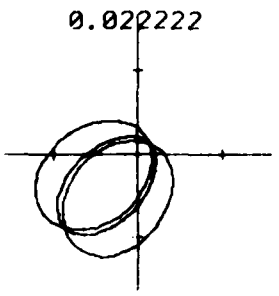
ANGLE 3 = 90
R+ = 0.5[illegible]
N+ = 30.000
Sgm+ = 776.[illegible]MPa
R- = 2.[illegible]
N- = 8.000
Sgm- = 1292.584MPa

ANGLE 4 = 0
R+ = 1.16[illegible]
N+ = 14.000
Sgm+ = 581.811MPa
R- = 1.13[illegible]
N- = 16.000
Sgm- = 561.417MPa

STRESS SPACE



STRAIN SPACE



FLEX. STIFFNESS MODULUS

D11	76.842N.m
D22	44.692N.m
D12	5.216N.m
D66	8.065N.m
D16	2.679N.m
D26	2.679N.m

INV.MAT.(kN.m)-1 COMPLIANCE

d11	13.240
d22	22.958
d12	-1.307
d66	127.697
d16	-3.963
d26	-7.192

E1-f	113.287GPa
E2-f	65.334GPa
E6-f	11.746GPa
ν21f	0.098
ν12f	0.056
ν61f	-0.299
ν16f	-0.031
ν62f	0.313
ν26f	-0.056

NORMALIZED CONST MODULUS

D11*	115.263GPa
D22*	67.038GPa
D12*	7.824GPa
D66*	12.097GPa
D16*	4.018GPa
D26*	4.018GPa

INV. MAT.(TPa)-1 COMPLIANCE

d11*	8.827
d22*	15.305
d12*	-0.871
d66*	85.131
d16*	-2.642
d26*	-4.794

M1 =	1.000MN
M2 =	0.000MN
M6 =	0.000MN

ANGLE 1 = -45
R+ = 0.001
Sgm+= 2349.468MPa

R- = 0.003
Sgm-= 4963.999MPa

ANGLE 2 = 45
R+ = 0.000
Sgm+= 1007.201MPa

R- = 0.001
Sgm-= 2954.782MPa

ANGLE 3 = 90
R+ = 0.000
Sgm+= 584.184MPa

R- = 0.002
Sgm-= 3149.567MPa

ANGLE 4 = 0
R+ = 0.000
Sgm+= 818.912MPa

R- = 0.000
Sgm-= 1143.139MPa

2. T300/5208, $[0_4/90_4]_S$ (Version 2)

T300/5208
ANGLE 1 = 90
No OF PLIES = 4
ANGLE 2 = 0
No OF PLIES = 4

N.OF CORE PLIES 0

IN PLANE STIFF.

A(i,j) MN/m

192.157	5.793	0.000
5.793	192.157	0.000
0.000	0.000	14.340

a(i,j) (kN/m)-1

5.208	-0.157	0.000
-0.157	5.208	0.000
0.000	0.000	69.735

E1-o	95.991GPa
E2-o	95.991GPa
E6-o	7.170GPa
ν21o	0.030
ν12o	0.030
ν61o	0.000
ν16o	0.000
ν62o	0.000
ν26o	0.000

NORMALIZED MATRI

A*(i,j) GPa

96.078	2.896	0.000
2.896	96.078	0.000
0.000	0.000	7.170

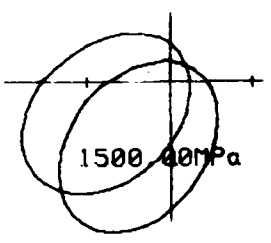
a*(i,j) TPa-1

10.417	-0.314	0.000
-0.314	10.417	0.000
0.000	0.000	139.470

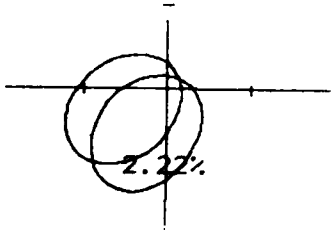
N1 =	1.00MN/m
N2 =	0.00MN/m
N6 =	0.00MN/m
ANGLE 1 =	90
R+ =	0.7462
N+ =	22.0000
Sgm+=	373.3955MPa
R- =	4.5376
N- =	4.0000
Sgm-=	2268.8188MPa

ANGLE 2 =	0
R+ =	1.3637
N+ =	12.0000
Sgm+=	681.8820MPa
R- =	2.2154
N- =	8.0000
Sgm-=	1107.7053MPa

STRESS SPACE



STRAIN SPACE



FLEX. STIFF.

D(i,j) N.m

106.918	1.931	0.000
1.931	21.186	0.000
0.000	0.000	4.780

d(i,j) (kN.m)-1

9.368	-0.853	0.000
-0.853	47.278	0.000
0.000	0.000	209.205

E1-f	160.113GPa
E2-f	31.726GPa
E6-f	7.169GPa
ν21f	0.091
ν12f	0.018
ν61f	0.000
ν16f	0.000
ν62f	0.000
ν26f	0.000

NORMALIZED FLEX.

D*(i,j) GPa

160.378	2.896	0.000
2.896	31.729	0.000
0.000	0.000	7.170

d*(i,j) TPa-1

6.245	-0.569	0.000
-0.569	31.518	0.000
0.000	0.000	139.470

M1 = 1.00MN
M2 = 0.00MN
M6 = 0.00MN

ANGLE 1 = 90
R+ = 0.000
Sgm+= 1253.541MPa

R- = 0.004
Sgm-= 7213.872MPa

ANGLE 2 = 0
R+ = 0.000
Sgm+= 1187.969MPa

R- = 0.001
Sgm-= 1705.573MPa

3. T300/5208, $[0/90/\pm45/CORE_4]_s$ (Version 1)

T300/5208

ANGLE 1 =-45
NO.OF PLIES = 1
ANGLE 2 = 45
NO.OF PLIES = 1
ANGLE 3 = 90
NO.OF PLIES = 1
ANGLE 4 = 0
NO.OF PLIES = 1
N.OF CORE PLIES 4

IN PLANE STIFFNE
MODULUS

A11	76.368MN/m
A22	76.368MN/m
A12	22.607MN/m
A66	26.880MN/m
A16	-0.000MN/m
A26	-0.000MN/m

COMPLIANCE

a11	14.352m/kN
a22	14.352m/kN
a12	-4.248m/kN
a66	37.201m/kN
a16	0.000m/kN
a26	0.000m/kN

E1-o	69.625GPa
E2-o	69.625GPa
E6-o	26.880GPa
ν21o	0.296
ν12o	0.296
ν61o	0.000
ν16o	0.000
ν62o	0.000
ν26o	0.000

NORMALIZED CONST
MODULUS

A11*	76.368GPa
A22*	76.368GPa
A12*	22.607GPa
A66*	26.880GPa
A16*	-0.000GPa
A26*	-0.000GPa

INV. MAT.(TPa)-1
COMPLIANCE

a11*	14.352
a22*	14.352
a12*	-4.248
a66*	37.201
a16*	0.000
a26*	0.000

N1 = 1.000MN/m
N2 = 0.000MN/m
N6 = 0.000MN/m

ANGLE 1 = -45
R+ = 0.346
N+ = 24.000
Sgm+= 346.995MPa

R- = 0.625
N = 12.000
Sgm-= 625.075MPa

ANGLE 2 = 45
R+ = 0.346
N+ = 24.000
Sgm+= 346.995MPa

R- = 0.625
N = 12.000
Sgm- = 625.075MPa

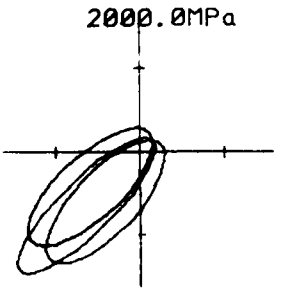
ANGLE 3 = 90
R+ = 0.296
N+ = 34.000
Sgm+= 296.119MPa

R- = 1.129
N = 8.000
Sgm- = 1129.284MPa

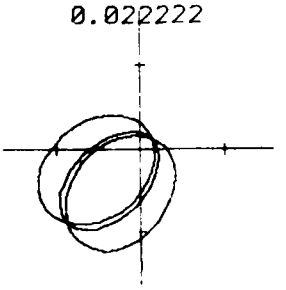
ANGLE 4 = 0
R+ = 0.581
N+ = 14.000
Sgm+= 581.811MPa

R- = 0.565
N = 16.000
Sgm- = 565.412MPa

STRESS SPACE



STRAIN SPACE



FLEX. STIFFNESS
MODULUS

D11	52.932N.m
D22	43.555N.m
D12	9.491N.m
D66	11.984N.m
D16	1.674N.m
D26	1.674N.m

INV.MAT.(kN.m)-1
COMPLIANCE

d11	19.716
d22	23.983
d12	-4.213
d66	84.129
d16	-2.166
d26	-2.762

E1-f	76.079GPa
E2-f	62.542GPa
E6-f	17.829GPa
ν21f	0.213
ν12f	0.175
ν61f	-0.109
ν16f	-0.025
ν62f	-0.115
ν26f	-0.032

NORMALIZED CONST MODULUS

D11*	79.398GPa
D22*	65.333GPa
D12*	14.237GPa
D66*	17.976GPa
D16*	2.511GPa
D26*	2.511GPa

INV. MAT.(TPa)-1 COMPLIANCE

d11*	13.144
d22*	15.989
d12*	-2.808
d66*	56.086
d16*	-1.444
d26*	-1.841

M1 = 1.000MN
M2 = 0.000MN
M6 = 0.000MN

ANGLE 1 = -45
R+ = 0.000
Sgm+= 617.319MPa

R- = 0.000
Sgm-= 1258.085MPa

ANGLE 2 = 45
R+ = 0.000
Sgm+= 486.485MPa

R- = 0.000
Sgm-= 1115.317MPa

ANGLE 3 = 90
R+ = 0.000
Sgm+= 342.839MPa

R- = 0.001
Sgm-= 1739.766MPa

ANGLE 4 = 0
R+ = 0.000
Sgm+= 606.418MPa

R- = 0.000
Sgm-= 684.798MPa

(E) PROGRAM LISTING

1. SYM - LAM 1

```
1:"SYM-LAM1":
  INPUT "COLOR ?
  (0, 1, 2, 3)";CC:
  COLOR CC
2:TEXT
3:DIM X(30), Y(20
  ), Z(20), U(25),
  A(31), B(31), V(
  24), A$(2)
4:DATA "11", "22"
  , "12", "66", "16
  ", "26"
5:RESTORE 4:FOR
  I=1TO 6.READ Q
  $(I):NEXT I
6:DATA "E1-", "E2
  -", "E6-", "ν21"
  , "ν12", "ν61", "
  ν16", "ν62", "ν2
  6"
7:RESTORE 6.FOR
  I=9TO 12:READ
  Q$(I):NEXT I
8:INPUT "MATERIA
  L N.=(M FOR ME
  NU)";G$:IF G$=
  "M"GOTO 195
9:I=VAL G$*10:
  GOSUB I:
  RESTORE I.READ
  W$, A, B, C, D, E, F
  , Q, R, S, T:
  LPRINT W$:GOTO
  200
10:DATA "300/520
  8", 181, 3, 10.3E
  3, .28, .1 3E3, .
  12 E-3, 1500, 15
  00, 40, 246, 68.
  RETURN
20:DATA "R(4)/550
  5", 204E3, 18.5E
  3, .23, 5.59E3, .
  125E-3, 1250, 25
  00, 61, 202, 67.
  RETURN
30:DATA "AS/3501"
  , 138E3, 8.96E3,
  30, 7.10E3, .12
  5E-3, 1447, 1447
  , .51, 7, 206, 93:
  RETURN
40:DATA "SCOTCHPL
  Y/1002", 38.6E3
  , 8.273, .26, 4.1
  4E3, .125E-3, 10
  62, 610, 31, 118,
  72:RETURN
50:DATA "KEVLAR 4
  9/EPOXY", 76E3,
  5.5E3, .34, 2.30
  E3, .125E-3, 140
  0, 235, 12, 53, 34
  :RETURN
60:DATA " ":
  RETURN
70:DATA " ":
  RETURN
80:DATA " ",
  RETURN
90:DATA " ":
  RETURN
100:DATA " ",
  RETURN
190:USING "&&&&###
  ###.###":
  RETURN
191:USING "&&&&&&&
  &&&&&&&&&":
  RETURN
195:FOR I=1TO 10:
  GOSUB I*10:
  RESTORE I*10:
  READ W$
197:PAUSE I;
  ";W$.NEXT I:
  GOTO 8
200:LF (1):A$(1)="
  MODULUS":A$(2)
  ="COMPLIANCE",
  AA=190:BB=191
210:PAUSE "DEFINE
  THE LAMINATE"
220:F=1/(1-C*C*B/A
  )
230:X(1)=F*A, X(2)=
  F*B, X(3)=F*C*B
  .X(4)=D
260:INPUT "HOW MAN
  Y ANGLES=";G
270:FOR I=1TO G
280:INPUT "ANGLE="
  ;Y(I)
290:H$="ANGLE "+
  STR$ (I)+" ="
300:LPRINT H$;Y(I)
310:INPUT "NO.OF P
  LIES=";Z(I)
315:LPRINT " NO.OF
  PLIES = ";Z(I
  )
316:NEXT I
317:INPUT "N.OF CO
  RE PLIES=(FLEX
  )";Z(0)
318:LPRINT USING "
  &&&&&&&&&&&&&&
  &###";"N.OF CO
  RE PLIES";Z(0)
320:PAUSE "ANSWER
  Y/N FOR LISTIN
  G"
323:INPUT "IN-PLAN
  E STIFFNESS -
  Y/N?";G$
324:X$="IN PLANE S
  TIFFNESS"
327:GOSUB 670:
  GOSUB 680
329:FOR I=1TO 6
330:GOSUB 200
335:X(10)=X(10)+2*
  E*Z(I)
340:U(I)=2*Z(I)*E
350:GOSUB 1100
360:NEXT I
365:E=65.1E-9.XX=
  1:U$="MN/m²".IF
  G$="Y"GOSUB 38
  0
375:GOTO 540
380:LF (1).COLOR 1
390:GOSUB BB:
  LPRINT X$, A$(T
  /6+1):LF (1)
400:GOSUB AA:FOR I
  =1TO 6
405:LPRINT CHR$ 7+
  Q$(I); X(I+T)*
  XX;U$
410:NEXT I:RETURN
490:LF (1):COLOR 1
497:U$="GPa"
500:FOR I=1TO 9
505:XX=1E-3:IF I>3
  THEN LET XX=1,
  U$=""
```

```
510:GOSUB 190:
    LPRINT @$(I+8)
    +CHR$ Z;A(I)*X
    X;U$
515:NEXT I
518:RETURN
540:GOSUB 800
560:X$="":Z=97:TT=
    6:XX=1E3:U$="m
    /kN":IF G$="Y"
    GOSUB 380
580:GOSUB 1200
585:Z=111
590:INPUT "ENGINEE
    RING CST - Y/N
    ? ";G$
592:IF G$="Y"GOSUB
    490
600:INPUT "NORMALI
    ZED CST - Y/N?
    ";G$
602:X$="NORMALIZED
     CONST."
605:Z=65:TT=12:XX=
    1E-3:U$="GPa":
    IF G$="Y"GOSUB
    630
610:X$="INV. MAT.(
    TPa)-1"
615:Z=97:TT=18:XX=
    1E6:U$="":IF G
    $="Y"GOSUB 630
620:GOTO 1300
630:LF (1):GOSUB 1
    91:LPRINT X$,A
    $((TT-9)/6+1):
    LF (1)
640:FOR I=1TO 6
645:GOSUB AA:
    LPRINT CHR$ Z+
    @$(I)+"*";U(I+
    TT)*XX;U$
650:NEXT I:RETURN
670:FOR J=10TO 16
672:X(J)=0:NEXT J
675:RETURN
680:FOR I=1TO 6
684:U(I)=0
688:NEXT I
690:RETURN
700:X(5)=(COS Y(I)
    )^4,X(6)=(COS
    Y(I))^3*SIN Y(
    I)
710:X(7)=(COS Y(I)
    *SIN Y(I))^2,X
    (8)=COS Y(I)*(
    SIN Y(I))^3
720:X(9)=(SIN Y(I)
    )^4
740:X(11)=X(1)*X(5
    )+X(2)*X(9)+2*
    X(7)*(X(3)+2*X
    (4))
750:X(12)=X(1)*X(9
    )+X(2)*X(5)+2*
    X(7)*(X(3)+2*X
    (4))
760:X(13)=X(7)*(X(
    1)+X(2)-4*X(4)
    )+X(3)*(X(5)+X
    (9))
770:X(14)=X(7)*(X(
    1)+X(2)-2*X(3)
    )+X(4)*(X(5)-2
    *X(7)+X(9))
780:X(15)=X(1)*X(6
    )-X(2)*X(8)+(X
    (8)-X(6))*(X(3
    )+2*X(4))
790:X(16)=X(1)*X(8
    )-X(2)*X(6)+(X
    (6)-X(8))*(X(3
    )+2*X(4))
795:RETURN
800:DT=U(1)*U(2)*U
    (4)+2*U(3)*U(6
    )*U(5)-U(2)*U(
    5)^2-U(4)*U(3)
    ^2-U(1)*U(6)^2
820:U(7)=(U(2)*U(4
    )-U(6)^2)/DT
825:U(8)=(U(1)*U(4
    )-U(5)^2)/DT
830:U(9)=(U(5)*U(6
    )-U(3)*U(4))/D
    T
840:U(10)=(U(1)*U(
    2)-U(3)^2)/DT
850:U(11)=(U(3)*U(
    6)-U(2)*U(5))/
    DT
860:U(12)=(U(3)*U(
    5)-U(1)*U(6))/
    DT
980:RETURN
1000:U(1)=1/P/Q,U
     (2)=1/P-1/Q
1010:U(3)=1/R/S,U
     (4)=1/R-1/S,
     U(5)=1/T/T
1020:U(3)=1/R/S,U
     (4)=1/R-1/S,
     U(5)=1/T/T
1025:O=-1/2
1030:U(6)=O*SQR(U(1
     )*U(3))
1040:U(7)=U(1)*X(
     1)^2+2*U(6)*
     X(1)*X(3)+U(
     3)*X(3)^2
1050:U(8)=U(1)*X(
     3)^2+2*U(6)*
     X(3)*X(2)+U(
     3)*X(2)^2
1060:U(9)=U(1)*X(
     1)*X(3)+U(6)
     *(X(1)*X(2)+
     X(3)^2)+U(3)
     *X(3)*X(2)
1070:U(10)=U(5)*X
     (4)^2,U(11)=
     U(2)*X(1)+U(
     4)*X(3),U(12
     )=U(2)*X(3)+
     U(4)*X(2)
1080:RETURN
1100:U(1)=U(1)+U(
     1)*X(11),U(2
     )=U(2)+U(1)*
     X(12),U(3)=U
     (3)+U(1)*X(1
     3)
1110:U(4)=U(4)+U(
     1)*X(14),U(5
     )=U(5)+U(1)*
     X(15),U(6)=U
     (6)+U(1)*X(1
     6)
1130:RETURN
1200:A(1)=1/X(10)
     /U(7),A(2)=1
     /X(10)/U(8),
     A(3)=1/X(10)
     /U(10)
1210:A(4)=-U(9)/U
     (7),A(5)=-U(
     9)/U(8),A(6)
     =U(11)/U(7)
1220:A(7)=U(11)/U
     (10),A(8)=U(
     12)/U(8),A(9
     )=U(12)/U(10
     )
1230:FOR J=1TO 6
1235:U(J+12)=U(J)
     /X(10)
1237:U(J+18)=U(J+
     6)*X(10)
1240:NEXT J
1270:RETURN
```

```
1300:TEXT :COLOR
     2
1320:INPUT "IN PL
     ANE STRENGTH
     - Y/N?";C$
1330:LF (1).IF G$
     ="N"GOTO 260
     0
1340:?-28.U$="MN/
     m":GOSUB 139
     0
1350:GOTO 1420
1390:LF (1):FOR I
     =1TO 13
1395:X$=CHR$ (2+
     MID$ (@$(I-2
     ),2,1)+" =";
     PRINT X$+"("
     +U$+")":
     INPUT @(I)
1400:GOSUB AA.
     LPRINT X$;@(
     I);U$
1410:NEXT I.
     RETURN
1420:X(12)=U(2)*K
     +U(9)*L+U(11
     )*M
1430:X(18)=U(9)*K
     +U(8/*L+U(12
     )*M
1440:X(19)=U(11)*
     K+U(12)*L+U(
     10)*M
1450:FOR I=1TO 6
1460:U$="ANGLE "+
     STR$ (I)+"
     "
1470:LF (1)
1480:USING "&&&&&
     &&&&####"
1490:IF G$="Y"
     LPRINT H$;Y(
     I)
1500.GOSUB 1550
1501:GOSUB 1000
1502:GOSUB 1600
1510:GOSUB 1650
1520:NEXT I
1530:GOTO 2600
1550:Y(I)=-Y(I)
1555:X(23)=(COS Y
     (I))^2,X(24)
     =(SIN Y(I))^
     2,X(25)=COS
     Y(I)*SIN Y(I
     )
1560:X(20)=X(17)*
     X(23)+X(18)*
     X(24)+X(19)*
     X(25)
1570:X(21)=X(17)*
     X(24)+X(18)*
     X(23)-X(19)*
     X(25)
1580:X(22)=2*X(25
     )*(X(18)-X(1
     7))+X(19)*(X
     (23)-X(24))
1585:Y(I)=-Y(I)
1590:RETURN
1600:U(13)=U(2)*X
     (20)^2+2*U(9
     )*X(20)*X(21
     )+U(8)*X(21)
     ^2+U(10)*X(2
     2)^2
1605:U(14)=U(11)*
     X(20)+U(12)*
     X(21)
1610:U(15)=U(14)/
     U(13)/2
1615:U(16)=-U(15)
     +SQR(U(15)^2+1
     /U(13))
1620:U(17)=U(15)+
     SQR(U(15)^2+1/
     U(13))
1625:B(1)=INT (X(
     10)/E/U(16)/
     2+1)*2,B(2)=
     INT (X(10)/E
     /U(17)/2+1)*
     2
1630:B(3)=U(16)/X
     (10),B(4)=U(
     17)/X(10)
1635:RETURN
1650:IF G$="N"
     THEN 1685
1653:USING "&&&&&
     #####.###"
1655:LPRINT "R+
     =";U(16)
1657:IF U$="MN"
     THEN 1665
1660:LPRINT "N+
     =";B(1)
1665:LPRINT "Sgm+
     =";B(3);"MPa
     "
1670:LPRINT "R-
     =";U(17)
1672:IF U$="MN"
     THEN 1680
1675:LPRINT "N-
     =";B(2)
1680:LPRINT "Sgm-
     =";B(4);"MPa
     "
1685.RETURN
1700:GRAPH .COLOR
     2
1701.GLCURSOR (12
     0,-120):
     SORGN
1702:LINE (0,-100
     )-(0,100),0,
     1
1703.LINE (-100,0
     )-(100,0),0,
     1
1705:INPUT "ANGLE
      NO.IS=";I
1710:IF I>GTHEN 2
     520
1711:AREAD Y(I)
1712:AREAD Z(I)
1715.INPUT "COLOR
      NO.IS=";Z
1717:X(26)=X(1),X
     (27)=X(2),X(
     28)=X(3),X(2
     9)=X(4)
1720:GOSUB 1000
1730:X(1)=U(2),X(
     2)=U(8),X(3)
     =U(9),X(4)=U
     (10)
1740:GOSUB 620
1770.GOSUB 700
1780:X(1)=X(26),X
     (2)=X(27),X(
     3)=X(28),X(4
     )=X(29)
1810:U(19)=X(1),
     U(20)=X(2),
     U(21)=X(3),
     U(22)=X(4)
1820.X(23)=(COS Y
     (I))^2,X(24)
     =(SIN Y(I))^
     2
1830:U(23)=U(11)*
     X(23)+U(12)*
     X(24),U(24)=
     U(11)*X(24)+
     U(12)*X(23)
1835.IF N=2THEN 2
     300
1840:B(19)=U(19)*
     U(2)^2+U(21)
     *U(2)*U(9)+U
     (20)*U(9)^2+
```

```
      U(22)*U(11)^
      2
1850: B(20)=U(19)*
      U(9)^2+U(21)
      *U(9)*U(8)+U
      (20)*U(8)^2+
      U(22)*U(12)^
      2
1860: B(21)=U(19)*
      U(7)*U(9)+U(
      21)*U(7)*U(8
      )+U(20)*U(9)
      *U(8)
1870: B(21)=B(21)+
      U(22)*U(11)*
      U(12)
1880. B(23)=U(23)*
      U(7)+U(24)*U
      (9)
1890. B(24)=U(23)*
      U(9)+U(24)*U
      (8)
1900. J(19)=B(19),
      U(20)=B(20),
      J(21)=B(21),
      U(23)=B(23),
      J(24)=B(24)
2300. J=U(19)-U(20
      )
2310: IF J=0AND U(
      21)>0THEN 23
      30
2315: IF J=0 0AND U(
      21)<0THEN 23
      35
2320. J(13)=(ATN (
      2*U(21)/(U(1
      9)-U(20)))/2
      2.GOTO 2340
2330. J(13)=45:
      GOTO 2340
2335: J(13)=-45
2340. J(14)=U(19)*
      (COS U(13))^
      2+2*U(21)*
      COS U(13)*
      SIN U(13)+U(
      20)*(SIN U(1
      3))^2
2350: J(15)=U(19)*
      (SIN J(13))^
      2-2*U(21)*
      SIN U(13)*
      COS U(13)+U(
      20)*(COS U(1
      3))^2
2360: U(16)=U(23)*
      COS U(13)+U(
      24)*SIN U(13
      )
2370: U(17)=-U(23)
      *SIN U(13)+U
      (24)*COS U(1
      3)
2380: U(18)=1+U(16
      )^2/U(14)/4+
      U(17)^2/U(15
      )/4
2390: X=J(U(18)/U(
      14)), Y=J(U(1
      8)/U(15))
2400: U=-U(16)/U(1
      4)/2, V=-U(17
      )/U(15)/2
2410: H=U*COS U(13
      )-V*SIN U(13
      ), M=U*SIN U(
      13)+V*COS U(
      13)
2420: U=H, V=M
2430: X=X*W, Y=Y*W,
      U=U*W, V=V*W
2480: A(0)=X*COS U
      (13)+U, B(0)=
      X*SIN U(13)+
      V
2490: FOR J=1TO 31
2500: A(J)=X*COS (
      12*J), B(J)=Y
      *SIN (12*J)
2510: M=A(J)*COS U
      (13)-B(J)*
      SIN U(13), H=
      A(J)*SIN U(1
      3)+B(J)*COS
      U(13)
2520. U(J)=M+U, B(J
      )=H+V
2540: LINE (A(J-1)
      ,B(J-1))-(A(
      J), B(J)), 0, 2
2550: NEXT J
2560: GOTO 1705
2570: LINE (-4, 60
      )-(4, -60), 0,
      1
2572: LINE (-4, 60)
      -(4, 60), 0, 1
2573: LINE (60, -4)
      -(60, 4), 0, 1
2574: LINE (-60, -4
      )-(-60, 4), 0,
      1
2575: IF N=1THEN
      LET K=60/XX/
      W:GOTO 2585
2580: K=60/W
2585: GLCURSOR (-6
      0, 90):SORGN
2586: IF N=2THEN 2
      588
2587: USING "#####
      #.#&&&":GOTO
      2590
2588: USING "##.##
      ####"
2590: LPRINT K;U$.
      TEXT .LF 10
2591. TEXT .RETURN
2600: XX=X(10):N=1
      U$="MPa":
      INPUT "FAIL.
      ENV. IN STRES
      S - Y/N?";G$
      :IF G$="N"
      THEN 2640
2601: USING "&&&&&
      &&&&&&&&&&&&
      &&&&&&&&"
2605: TEXT .LF (2)
2610: W=30
2615: LPRINT "    S
      TRESS SPACE"
2620: GOSUB 1700
2630: INPUT "NEW S
      CALE    Y/N?"
      ;G$:IF G$="N
      "GOTO 2640
2635: INPUT "W= ?"
      ;W.GO'O 2615
2640. N 2.U$=""":
      INPUT "FAIL.
      ENV. IN STRAI
      N - Y/N?";G$
      :IF G$="N"
      THEN 2700
2641: USING "&&&&&
      &&&&&&&&&&&&
      &&&&&&&&&&&"
2645: TEXT .LF (2)
2650. W=2700
2655. LPRINT "    S
      TRAIN SPACE"
2660. GOSUB 1700
2670: INPUT "NEW S
      CALE ?Y/N".G
      $.IF G$="N"
      GOTO 2700
2680: INPUT "W= ?"
      ;W:GOTO 2655
```

```
2700: GOSUB BR.LF
      (1)
2710. INPUT "FLEXU
      RAL STIFFNES
      S - Y/N? ", G$
2720: X$="FLEX. ST
      IFFNESS"
2740. LF (1):GOSUB
      670:GOSUB 68
      0
2765: X(10)=Z(0)*E
2770. FOR I=1TO 6
2780: GOSUB 700
2785: X(10)=X(10)+
      E*Z(I)
2790. J(I)=2/3*(X(
      10)^3-(X(10)
      Z(I)*E)^3)
2800. GOSUB 1100
2820: NEXT I
2850: W=68:TT=0:XX
      =1E6.U$="N.m
      ":IF G$="Y"
      GOSUB 380
2910: GOSUB 800
2920. X$="INV.MAT.
      (kN.m)^-1"
2930. Z=100.TT=6.X
      X=1E-3.U$="
      :IF G$="Y"
      GOSUB 380
2940: X(10)=2*X(10
      )^3/3
2950: GOSUB 1200
2960: Z=102
2965. INPUT "ENGIN
      EERING CONST
      ANTS";G$
2970. IF G$="Y"
      GOSUB 490
3000. INPUT "NORM.
      FLEX.CONST
      ANTS";G$
3005. X$="NORMAL 2
      ND CONST"
3010. Z=68:TT=12:X
      X=1E-3:U$="G
      Pa":IF G$="Y
      "GOSUB 630
3040: X$="INV. MAT
      (Pa)^-1"
3050. Z=100:TT=18:
      XX=1E6.U$="
      IF G$="Y"
      GOSUB 630
3160: BLOK 2
3165: INPUT "  FLE
      XURAL STRENG
      TH - Y/N? ";
      G$
3170: IF G$="N"
      GOTO 3330
3180: Z=77:U$="MN"
      :GOSUB 1390
3200: X(17)=V(7)*K
      +V(9)*L+V(11
      )*M
3210: X(18)=V(9)*K
      +V(8)*L+V(12
      )*M
3220: X(19)=V(11)*
      K+V(12)*L+V(
      10)*M
3230: A(0)=Z(0)*E
3232. W=X(10)
3235: X(10)=1/6*
      EXP (2/3*LN
      (X(10)*12))
3240: FOR I=1TO 6
3250. A(I)=A(I-1)+
      Z(I)*E
3255: LF (1)
3260: H$="ANGLE "+
      STR$ (I)+" =
      "
3268. IF G$="N"
      GOTO 3275
3270: USING "&&&&&
      &&&&&&&&###"
      LPRINT H$;Y(
      I)
3275. GOSUB 1555
3277. Y(I)=-Y(I)
3280. GOSUB 1000
3285: X(20)=X(20)*
      A(I),X(21)=X
      (21)*A(I),X(
      22)=X(22)*A(
      I)
3290: GOSUB 1600
3300: GOSUB 1650
3310. NEXT I
3320: X(10)=W
3330: GOTO 323
```

2. SYM - LAM 2

```
1:"SYM-LAM2":
  INPUT "COLOR ?
  (0,1,2,3)";CC
  :COLOR CC
2:GRAPH .ROTATE
  1.KK=1:
  GLCURSOR (200,
  0).I1=1:SORGN
3:DIM X(30),Y(20
  ),C(3,3),U(24)
  ,T$(2),Z(20),U
  (25),A(31),B(3
  1)
7.DATA 1,3,5,3,2
  .6,5,6,4.FOR I
  =1TO 3:FOR J=1
  TO 3:READ C(I,
  J):NEXT J:NEXT
  I.GOSUB 140
8:INPUT "MATERIA
  L  N. =(M FOR M
  ENU)";G$.IF G$
  ="M"GOTO 195
9:I=VAL G$*10:
  GOSUB I.
  RESTORE I.READ
  W$,A,B,C,D,E,F
  ,Q,R,S,T:
  LPRINT W$:GOTO
  200
10.DATA "T300/520
  8",181E3,10.3E
  3,.28,2.12E3,.
  125E-3,1500,15
  00,40,246,68:
  RETURN
20:DATA "B(4)/550
  5",204E3,18.5E
  3,.23,5.59E3,1
  25E-3,1260,250
  0,61,202,67.
  RETURN
30:DATA "AS/3501
  .138E3,8.96E3,
  .30,2.10E3,.12
  5E-3,1442,1442
  ,51.2,206,93.
  RETURN
40.DATA "SCOTCHPL
  Y 1002 .38.6E3
  ,8.22E3,.26,4.
  14E3,.125E-3,1
  086,610,31,118
  ,22.RETURN
50:DATA "KEVLAR 4
  9/EPOXY",76E3,
  5.5E3,.34,2.30
  E3,.125E-3,140
  0,235,12,53,34
  :RETURN
60:DATA "":RETURN
70:DATA "":RETURN
80:DATA "":RETURN
90:DATA "":RETURN
100:DATA "":RETURN
140:DATA "E1-","E2
  -","E6-","U21"
  ,"U12","U61","
  U16","U62","U2
  6"
150:RESTORE 140:
  FOR I=9TO 17:
  READ Q$(I):
  NEXT I.RETURN
190:USING "&&&&&&&
  &&&&&&&&&&&&&":
  RETURN
191:USING "########
  .###":RETURN
195:FOR I=1TO 10:
  GOSUB I*10.
  RESTORE I*10:
  READ W$
197.PAUSE I;" -
  ";W$:NEXT I.
  GOTO 8
200:T$(1)="".T$(2)
  ="*".AA=191.PP
  =4E3:LL=5E3
210:PAUSE "DEFINE
  THE LAMINATE"
220:F=1/(1-C*C*B/A
  )
230:X(1)=F*A,X(2)=
  F*B,X(3)=F*C*B
  ,X(4)=0
260:INPUT "HOW MAN
  Y ANGLES=";G
270:I=0:FOR I=1TO
  G:I=J+I
280:INPUT "ANGLE="
  ;Y(I)
290:H$="ANGLE "+
  STR$ (I)+" ="
300:GOSUB LL:
  LPRINT USING H$;Y(I)
310:INPUT "NO.OF P
  LIES=";Z(I)
313:GOSUB LL:
  LPRINT " No OF
  PLIES = ";Z(I
  ):IF J=4GOSUB
  PP:J=0
315:NEXT I
316:INPUT "N.OF CO
  RE PLIES=(FLEX
  )";Z(0)
317:GOSUB LL:GOSUB
  LL:LPRINT
  USING "&&&&&&&
  &&&&&&&&&###";"
  N.OF CORE PLIE
  S";Z(0)
318.KK=1.I:GOSUB P
  P
320:PAUSE "ANSWER
  Y/N FOR"
322:INPUT "IN-PLAN
  E STIFFNESS -
  Y/N?";G$:X$="I
  N PLANE STIFF.
  ";N=1
328:GOSUB 620.
  GOSUB 680
329:FOR I=1TO 6
330.GOSUB 700
335:X(10)=X(10)+2*
  E*Z(I)
340:U(I)=2*Z(I)*E
350:GOSUB 1100
360:NEXT I
365.GOSUB 800:
  GOSUB 1200
370:IF G$="Y"GOSUB
  620:GOSUB 385
375.GOTO 590
385:Z=65.W=19:TT=0
  .U$="MN/m".XX=
  1.GOSUB 630
390:Z=37.W=20:TT=6
  U$="(kN/m)-1"
  XX=1E3.GOSUB
  630
392.GOSUB PP:
  RETURN
497:KK=1.U$="GPa"
500:FOR I=1TO 9
505:XX=1E-3.IF I>3
  THEN LET XX=1,
  U$=""
510:GOSUB LL:
```

```
    LPRINT USING "
    &&&&&";@$(1+8)
    +CHR$ Z;USING
    "####.###";A(I
    )*XX;USING '&&
    &";U$
515:NEXT I:GOSUB P
    P:RETURN
590:INPUT "ENGINEE
    RING CST-  Y/N
    ? ";G$
592:Z=111:IF G$="Y
    "GOSUB 497
600:INPUT "NORMALI
    ZED CST -  Y/N
    ? ";G$:X$="NOR
    MALIZED MATRIX
    ":N=2
605:IF G$="Y"GOSUB
    620:GOSUB 625
610:GOTO 1300
620:KK=2:GOSUB 190
    :LPRINT X$:II=
    1:GOSUB LL:
    RETURN
625:GOSUB LL:Z=65:
    W=19:U$="GPa":
    TT=12:XX=1E-3:
    GOSUB 630
627:GOSUB LL:Z=97:
    W=20:U$="TPa-1
    ":TT=18.XX=1E6
    :GOSUB 630:
    GOSUB PP.
    RETURN
630:GOSUB 190:
    LPRINT CHR$ 7+
    T$(N)+"(1,J)
    "+U$;@$(W):
    GOSUB AA:GOSUB
    LL
634:FOR I=1TO 3:
    FOR J=1TO 3
636:LPRINT U(I,J
    )+TT)*XX:NEXT
    I:GOSUB LL:
    NEXT I:RETURN
670:FOR J=10TO 16:
    X(J)=0:NEXT J:
    RETURN
680:FOR I=1TO 6:U(
    I)=0:NEXT I.
    RETURN
700:X(5)=(COS Y(I)
    )^4,X(6)=(COS
    Y(I))^3*SIN Y(
    I)
710:X(7)=(COS Y(I)
    *SIN Y(I))^2,X
    (8)=COS Y(I)*(
    SIN Y(I))^3
720:X(9)=(SIN Y(I)
    )^4
740:X(11)=X(1)*X(5
    )+X(2)*X(9)+2*
    X(7)*(X(3)+2*X
    (4))
750:X(12)=X(1)*X(9
    )+X(2)*X(5)+2*
    X(7)*(X(3)+2*X
    (4))
760:X(13)=X(7)*(X(
    1)+X(2)-4*X(4)
    )+X(3)*(X(5)+X
    (9))
770:X(14)=X(7)*(X(
    1)+X(2)-2*X(3)
    )+X(4)*(X(5)-2
    *X(7)+X(9))
780:X(15)=X(1)*X(6
    )-X(2)*X(8)+(X
    (8)-X(6))*(X(3
    )+2*X(4))
790:X(16)=X(1)*X(8
    )-X(2)*X(6)+(X
    (6)-X(8))*(X(3
    )+2*X(4))
795:RETURN
800:DT=U(1)*U(2)*U
    (4)+2*U(3)*U(6
    )*U(5)-U(2)*U(
    5)^2-U(4)*U(3)
    ^2-U(1)*U(6)^2
820:U(7)=(U(2)*U(4
    )-U(6)^2)/DT
825:U(8)=(U(1)*U(4
    )-U(5)^2)/DT
830:U(9)=(U(5)*U(6
    )-U(3)*U(4))/D
    T
840:U(10)=(U(1)*U(
    2)-U(3)^2)/DT
850:U(11)=(U(3)*U(
    6)-U(2)*U(5))/
    DT
860:U(12)=(U(3)*U(
    5)-U(1)*U(6))/
    DT:RETURN
1000:U(1)=1/P/Q,U
     (2)=1/P-1/Q
1010:U(3)=1/R/S,U
     (4)=1/R-1/S,
     U(5)=1/T/T
1020:U(3)=1/R/S,U
     (4)=1/R-1/S,
     U(5)=1/T/T
1025:D=-.5:U(6)=D
     *SQR(U(1)*U(3)
     )
1040:U(7)=U(1)*X(
     1)^2+2*U(6)*
     X(1)*X(3)+U(
     3)*X(3)^2
1050:U(8)=U(1)*X(
     3)^2+2*U(6)*
     X(3)*X(2)+U(
     3)*X(2)^2
1060:U(9)=U(1)*X(
     1)*X(3)+U(6)
     *(X(1)*X(2)+
     X(3)^2)+U(3)
     *X(3)*X(2)
1070:U(10)=U(5)*X
     (4)^2,U(11)=
     U(2)*X(1)+U(
     4)*X(3),U(12
     )=U(2)*X(3)+
     U(4)*X(2).
     RETURN
1100:U(1)=U(1)+U(
     1)*X(11),U(2
     )=U(2)+U(1)*
     X(12),U(3)=U
     (3)+U(1)*X(1
     3)
1110:U(4)=U(4)+U(
     1)*X(14),U(5
     )=U(5)+U(1)*
     X(15),U(6)=U
     (6)+U(1)*X(1
     6):RETURN
1200:A(1)=1/X(10)
     /U(7),A(2)=1
     /X(10)/U(8),
     A(3)=1/X(10)
     /U(10)
1210:A(4)=-U(9)/U
     (7),A(5)=-U(
     9)/U(8),A(6)
     =U(11)/U(7)
1220:A(7)=U(11)/U
     (10),A(8)=U(
     12)/U(8),A(9
     )=U(12)/U(10
     )
1230:FOR J=1TO 6
1235:U(J+12)=U(J)
     /X(10)
1240:U(J+18)=U(J+
     6)*X(10).
```

```
      NEXT I:
      RETURN
1300: INPUT "IN-PL
      ANE STRENGTH
       Y/N? ";G$
1305: IF G$="N"
      GOTO 2600
1310: FOR I=1 TO 3:U$="MN/
      M
1320: GOSUB 1390:
      GOTO 1420
1390: GOSUB LL:FOR
      I=1 TO 13
1395: PRINT CHR$ (
      +MID$ (@$(I-
      2),2,1)+"
       ("+U$+")":
      INPUT @(I)
1400: LPRINT USING
      &&&&&";CHR$
      2+MID$ (@$(I
      2),2,1)+"
      "USING "###
      .##&&&&&&":@
      (I); I$:GOSUB
      LL:NEXT I:
      RETURN
1420: X(17)=U(7)*K
      +U(9)*L+U(11
      )*M
1430. X(18)=U(8)*K
      +U(8)*L+U(12
      )*M
1440. X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
1450. KK=1.0:FOR
      I=1TO 6
1500. GOSUB 1550:
      GOSUB 1000.
      GOSUB 1600.
      GOSUB 1650:
      GOSUB PP:
      NEXT I
1530. GOTO 2600
1550: Y(I)=-Y(I)
1555: X(23)=(COS Y
      (I))^2, X(24)
      =(SIN Y(I))^
      2, X(25)=COS
      Y(I)*SIN Y(I
      )
1560. X(20)=X(17)*
      X(23)+X(18)*
      X(24)+X(19)*
      X(25)
1570: X(21)=X(17)*
      X(24)+X(18)*
      X(23)-X(19)*
      X(25)
1580: X(22)=2*X(25
      )*(X(18)-X(1
      7))+X(19)*(X
      (23)-X(24))
1585: Y(I)=-Y(I):
      RETURN
1600: U(13)=U(7)*X
      (20)^2+2*U(9
      )*X(20)*X(21
      )+U(8)*X(21)
      ^2+U(10)*X(2
      2)^2
1605: U(14)=U(11)*
      X(20)+U(12)*
      X(21)
1610: U(15)=U(14)/
      U(13)/2
1615: U(16)=-U(15)
      +SQR(U(15)^2+1
      /U(13))
1620: U(17)=U(15)+
      SQR(U(15)^2+1/
      U(13))
1625: B(1)=INT (X(
      10)/E/U(16)/
      2+1)*2, B(2)=
      INT (X(10)/E
      /U(17)/2+1)*
      2
1630: B(3)=U(16)/X
      (10), B(4)=U(
      17)/X(10):
      RETURN
1650: USING "&&&&&
      &&&&#####"
1652: GOSUB LL:
      LPRINT "ANGL
      E "+STR$ (I)
      +" =";Y(I)
1653: USING "&&&&&
      ######.####"
1655: GOSUB LL:
      LPRINT "R+
      =";U(16)
1657: IF U$="MN"
      THEN 1665
1660: GOSUB LL:
      LPRINT "N+
      =";B(1)
1665: GOSUB LL:
      LPRINT "Sgm+
      =";B(3);"MPa
      "
1670: GOSUB LL:
      LPRINT "R-
      =";U(17)
1672: IF U$="MN"
      THEN 1680
1675: GOSUB LL:
      LPRINT "N-
      =";B(2)
1680: GOSUB LL:
      LPRINT "Sgm-
      =";B(4);"MPa
      ":RETURN
1700: IF N=1THEN
      LET K=60/XX/
      W:GOTO 1704
1702: K=60/W*100
1704: PAUSE USING
      "#######.##&&
      &&&&&&&&&&&&
      ";"SCALE UNI
      T IS";K;U$
1706: INPUT "NEW S
      CALE ?Y/N";G
      $
1708: IF G$="N"
      GOTO 1710
1709: INPUT "W = ?
      ";W:GOTO 17
      00
1710: GLCURSOR (-7
      0,-140):
      SORGN
1715: LINE (0,-120
      )-(0,120),0,
      1
1720: LINE (-100,0
      )-(50,0),0,1
1725: INPUT "ANGLE
      NO. IS=";I
1730: IF I>GTHEN 2
      570
1735: AREAD Y(I)
1740: AREAD Z(I)
1750. INPUT "COLOR
      NO. IS=";Z
1760: X(26)=X(1), X
      (27)=X(2), X(
      28)=X(3), X(2
      9)=X(4)
1770: GOSUB 1000
1780: X(1)=U(7), X(
      2)=U(8), X(3)
      =U(9), X(4)=U
      (10)
1790: GOSUB 670:
      GOSUB 700
1800: X(1)=X(26), X
      (2)=X(27), X(
      3)=X(28), X(4
      )=X(29)
```

```
1810:U(19)=X(11),
     U(20)=X(12),
     U(21)=X(13),
     U(22)=X(14)
1820.X(23)=(COS Y
     (1))^2,X(24)
     =(SIN Y(1))^
     2
1830:U(23)=U(11)*
     X(23)+U(12)*
     X(24),U(24)=
     U(11)*X(24)+
     U(12)*X(23)
1835:IF N=2THEN 2
     300
1840:B(19)=U(19)*
     U(7)^2+U(21)
     *U(7)*U(9)+U
     (20)*U(9)^2+
     U(22)*U(11)^
     2
1850:B(20)=U(19)*
     U(9)^2+U(21)
     *U(9)*U(8)+U
     (20)*U(8)^2+
     U(22)*U(12)^
     2
1860:B(21)=U(19)*
     U(7)*U(9)+U(
     21)*U(7)*U(8
     )+U(20)*U(9)
     *U(8)
1870:B(21)=B(21)+
     U(22)*U(11)*
     U(12)
1880:B(23)=U(23)*
     U(7)+U(24)*U
     (9)
1890:B(24)=U(23)*
     U(9)+U(24)*U
     (8)
1900:U(19)=B(19),
     U(20)=B(20),
     U(21)=B(21),
     U(23)=B(23),
     U(24)=B(24)
2300:D=U(19)-U(20
     )
2310:IF D=0AND U(
     21)>0THEN 23
     30
2315:IF D=0AND U(
     21)<0THEN 23
     35
2320:U(13)=(ATN (
     2*U(21)/(U(1
     9)-U(20))))/
     2:GOTO 2340
2330:U(13)=45:
     GOTO 2340
2335:U(13)=-45
2340:U(14)=U(19)*
     (COS U(13))^
     2+2*U(21)*
     COS U(13)*
     SIN U(13)+U(
     20)*(SIN U(1
     3))^2
2350:U(15)=U(19)*
     (SIN U(13))^
     2-2*U(21)*
     SIN U(13)*
     COS U(13)+U(
     20)*(COS U(1
     3))^2
2360:U(16)=U(23)*
     COS U(13)+U(
     24)*SIN U(13
     )
2370:U(17)=-U(23)
     *SIN U(13)+U
     (24)*COS U(1
     3)
2380:U(18)=1+U(16
     )^2/U(14)/4+
     U(17)^2/U(15
     )/4
2390:X=SQR ABS (U(18
     )/U(14)),Y=S
     QR ABS (U(18)/U
     (15))
2400:U=-U(16)/U(1
     4)/2,V=-U(17
     )/U(15)/2
2410:W=U*COS U(13
     )-V*SIN U(13
     ),M=U*SIN U(
     13)+V*COS U(
     13)
2420:U=W,V=M
2430:X=X*W,Y=Y*W,
     U=U*W,V=V*W
2480:A(0)=X*COS U
     (13)+U,B(0)=
     X*SIN U(13)+
     V
2490:FOR J=1TO 31
2500:A(J)=X*COS (
     12*J),B(J)=Y
     *SIN (12*J)
2510:M=A(J)*COS U
     (13)-B(J)*
     SIN U(13),W=
     A(J)*SIN U(1
     3)+B(J)*COS
     U(13)
2520:A(J)=M+U,B(J
     )=W+V
2540:LINE (B(J-1)
     ,-A(J-1))-(B
     (J),-A(J)),0
     ,Z:NEXT J:
     GOTO 1725
2570:LINE (-4,-60
     )-(4,-60),0,
     1
2572:LINE (-4,60)
     -(4,60),0,1
2573:LINE (60,-4)
     -(60,4),0,1
2574:LINE (-60,-4
     )-(-60,4),0,
     1
2585:GLCURSOR (-6
     0,90):SORGN
2590:LPRINT K;U$:
     RETURN
2600:XX=X(10):N=1
     :U$="MPa":
     INPUT "FAIL.
     ENV. IN STRES
     S-Y/N?";G$:
     IF G$="N"
     THEN 2640
2610:GOSUB 190:
     GOSUB LL:W=1
     6
2615.LPRINT "   S
     TRESS SPACE"
2620:GOSUB 1700:
     GLCURSOR (13
     0,230):SORGN
     :KK=2:GOSUB
     PP
2640:N=2:U$="%":
     INPUT "FAIL.
     ENV. IN STRAI
     N -Y/N?";G$:
     IF G$="N"
     THEN 2700
2650:GOSUB 190:W=
     2700
2655:LPRINT "   S
     TRAIN SPACE"
2660:GOSUB 1700.
     GLCURSOR (13
     0,230):SORGN
     :KK=2:GOSUB
     PP
2700:GOSUB 190:
     INPUT "FLEXU
     RAL STIFFNES
```

```
      S -Y/N?";G$:
      X$="FLEX. ST
      IFF.".N=1
2245:GOSUB 620
2250:GOSUB 680
2265:X(10)=Z(0)*E
2270:FOR I=1TO 1
2280:GOSUB 700
2285:X(10)=X(10)+
      E*Z(I)
2290:U(I)=2/3*(X(
      10)^3-(X(10)
      Z(I)*E)^3)
2800:GOSUB 1100
2820:NEXT I
2830:GOSUB 800
2840:IF G$="Y"
      GOSUB 620:
      GOSUB 2880
2860:GOTO 2940
2880:Z=68.W=19:TT
      =0:U$="N.m":
      XX=1E6:GOSUB
      630
2890:Z=100:W=20:T
      T=6:U$="(kN.
      m)-1".XX=1E
      3.GOSUB 630
2900:KK=2.GOSUB P
      P
2940:X(10)=2*X(10
      )^3/3
2950:GOSUB 1200
2960:Z=102.INPUT
      "ENGIN.FLEX.
      CST  Y/N?",G
      $
2970:IF G$="N"
      GOTO 3000
2975:GOSUB 497
3000:INPUT "NORM.
      FLEX.CST  Y/
      N?";G$.N=2:X
      $="NORMALIZE
      D FLEX."
3010:IF G$="N"
      GOTO 3120
3020:GOSUB 620
3022:Z=68:W=19:U$
      ="GPa".TT=12
      :XX=1E-3:
      GOSUB 630
3025:Z=100:W=20:U
      $="TPa-1".TT
      =18:XX=1E6:
      GOSUB 630
3030:KK=2:GOSUB P
      P
3120:KK=1.05:
      INPUT "  FLE
      XURAL STRENG
      TH  -Y/N? ";
      G$
3130:IF G$="N"
      GOTO 3330
3170:Z=77:U$="MN"
      :GOSUB 1390
3200:X(17)=U(7)*K
      +U(9)*L+U(11
      )*M
3210:X(18)=U(9)*K
      +U(8)*L+U(12
      )*M
3220:X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
3230:A(0)=Z(0)*E
3232:W=X(10)
3235:X(10)=1/6*
      EXP (2/3*LN
      (X(10)*12))
3240:FOR I=1TO G
3250:A(I)=A(I-1)+
      Z(I)*E
3275:GOSUB 1555
3277:Y(I)=-Y(I)
3280:GOSUB 1000
3285:X(20)=X(20)*
      A(I),X(21)=X
      (21)*A(I),X(
      22)=X(22)*A(
      I)
3300:GOSUB 1600:
      GOSUB 1650:
      GOSUB PP:
      NEXT I
3330:GOTO 322
4000:GLCURSOR (0,
      -230*KK):
      SORGN :LINE
      (0,10)-(-200
      ,10),0:
      GLCURSOR (0,
      0)
4010:II=0:RETURN
5000:GLCURSOR (-2
      0*II,0):II=I
      I+1:RETURN
```

```
1:"SYM-LAM3"
3:DIM X(30),Y(20
),Z(20),U(25),
V(24),A$(2),A(
10),B(31)
4:DATA "11 , 22"
, 12","66","16
", 26"
5.RESTORE 4:FOR
I=1TO 6.READ @
$(I):NEXT I
6:DATA "E1-","E2
-","E6-","v21-
","v12-","v61-
","v16-","v62-
", v26-"
7:RESTORE 6:FOR
I=9TO 17.READ
@$(I):NEXT I
8:INPUT "MATERIA
L N.=(N FOR ME
NU)";G$:IF G$=
"M"GOTO 195
9:I=VAL G$*10:
GOSUB I:
RESTORE I:READ
W$,A,B,C,D,E,P
,Q,R,S,T:PRINT
W$:GOTO 200
10:DATA "T300/520
8",181E3,10.3E
3,.28,7.17E3,.
125E-3,1500,15
00,40,246,68:
RETURN
20:DATA "B(4)/550
5",204E3,18.5E
3,.23,5.59E3,.
125E-3,1260,25
00,61,202,67:
RETURN
30:DATA "AS/3501"
,138E3,8.96E3,
.30,7.10E3,.12
5E-3,1447,1447
,51.7,206,93:
RETURN
40:DATA "SCOTCHPL
Y/1002",38.6E3
,8.273,.26,4.1
4E3,.125E-3,10
62,610,31,118,
72:RETURN
50:DATA "KEVLAR 4
9/EPOXY",76E3,
5.5E3,.34,2.30
E3,.125E-3,140
0,235,12,53,34
:RETURN
60:DATA ""
70:DATA ""
80:DATA ""
90:DATA ""
100:DATA ""
190:USING "&&&&&##
####.###":
RETURN
191:USING "&&&&&&&
&&&&&&&&&&&&"
:RETURN
195:FOR I=1TO 10:
GOSUB I*10:
RESTORE I*10:
READ W$
197:PAUSE USING "#
##";I;"
";W$:NEXT I:
GOTO 8
200:A$(1)="MODULUS
":A$(2)="COMPL
IANCE":AA=190:
BB=191
210:PAUSE "DEFINE
THE LAMINATE"
220:F=1/(1-C*C*B/A
)
230:X(1)=F*A,X(2)=
F*B,X(3)=F*C*B
,X(4)=D
260:INPUT "HOW MAN
Y ANGLES=";G
270:FOR I=1TO G
280:INPUT "ANGLE="
;Y(I)
290:H$="ANGLE "+
STR$ (I)+" ="
300:PRINT H$;Y(I)
310:INPUT "NO.OF P
LIES=";Z(I)
315:PRINT " NO.OF
PLIES = ";Z(I)
316:NEXT I
317:INPUT "N.OF CO
RE PLIES=(FLEX
)";Z(0)
318:PRINT USING "&
&&&&&&&&&&&&&
###";"N.OF COR
E PLIES";Z(0)
320:PAUSE "ANSWER
Y/N FOR LISTIN
G"
323:INPUT "IN-PLAN
E STIFFNESS -
Y/N?";G$
327:GOSUB 670:
GOSUB 680
329:FOR I=1TO G
330:GOSUB 700
335:X(10)=X(10)+2*
E*Z(I)
340:U(I)=2*Z(I)*E
350:GOSUB 1100
360:NEXT I
365:Z=65:TT=0:XX=1
:U$="MN/m".IF
G$="Y"GOSUB 38
0
375:GOTO 540
380:GOSUB BB:PRINT
A$(TT/6+1)
400:GOSUB AA:FOR I
=1TO 6
405:PRINT CHR$ Z+@
$(I);U(I+TT)*X
X;U$
410:NEXT I.RETURN
490:U$="GPa"
500:FOR I=1TO 9
505:XX=1E-3:IF I>3
THEN LET XX=1,
U$=""
510:GOSUB 190:
PRINT @$(I+8)+
CHR$ Z;A(I)*XX
;U$
515:NEXT I
518:RETURN
540:GOSUB 800
560:X$="":Z=97.TT=
6:XX=1E3:U$="m
/kN":IF G$="Y"
GOSUB 380
580:GOSUB 1200
585:Z=111
590:INPUT "ENGINEE
RING CST - Y/N
? ";G$
```

```
592: IF G$="Y"GOSUB
     490
600: N=2: INPUT "NOR
     MALIZED CST -
     Y/N? ";G$
605: Z=65: W=1: TT=12
     : XX=1E-3. U$="G
     Pa": IF G$="Y"
     GOSUB 630
615. Z=92: W=2: TT=18
     . XX=1E6: U$="TP
     a-1". IF G$="Y"
     GOSUB 630
620: GOTO 1300
630. GOSUB 191:
     PRINT A$(W)
640: FOR I=1TO 6
645: GOSUB AA: PRINT
     CHR$ Z+Q$(I)+"
     *"; U(I+TT)*XX;
     U$
650: NEXT I. RETURN
670: FOR J=10TO 16
672: X(J)=0: NEXT J
675: RETURN
680: FOR I=1TO 6
684: U(I)=0
688: NEXT I
690. RETURN
700: X(5)=(COS Y(I)
     )^4, X(6)=(COS
     Y(I))^3*SIN Y(
     I)
710: X(7)=(COS Y(I)
     *SIN Y(I))^2, X
     (8)=COS Y(I)*(
     SIN Y(I))^3
720: X(9)=(SIN Y(I)
     )^4
740: X(11)=X(1)*X(5
     )+X(2)*X(9)+2*
     X(7)*(X(3)+2*X
     (4))
750. X(12)=X(1)*X(9
     )+X(2)*X(5)+2*
     X(7)*(X(3)+2*X
     (4))
760. X(13)=X(7)*(X(
     1)+X(2)-4*X(4)
     )+X(3)*(X(5)+X
     (9))
770: X(14)=X(7)*(X(
     1)+X(2)-2*X(3)
     )+X(4)*(X(5)-2
     *X(7)+X(9))
780: X(15)=X(1)*X(6
     )-X(2)*X(8)+(X
     (8)-X(6))*(X(3
     )+2*X(4))
790: X(16)=X(1)*X(8
     )-X(2)*X(6)+(X
     (6)-X(8))*(X(3
     )+2*X(4))
795: RETURN
800: DT=U(1)*U(2)*U
     (4)+2*U(3)*U(6
     )*U(5)-U(2)*U(
     5)^2-U(4)*U(3)
     ^2-U(1)*U(6)^2
820: U(7)=(U(2)*U(4
     )-U(6)^2)/DT
825: U(8)=(U(1)*U(4
     )-U(5)^2)/DT
830: U(9)=(U(5)*U(6
     )-U(3)*U(4))/D
     T
840: U(10)=(U(1)*U(
     2)-U(3)^2)/DT
850: U(11)=(U(3)*U(
     6)-U(2)*U(5))/
     DT
860: U(12)=(U(3)*U(
     5)-U(1)*U(6))/
     DT
980: RETURN
 1000: U(1)=1/P/Q, U
       (2)=1/P-1/Q
 1010: U(3)=1/R/S, U
       (4)=1/R-1/S,
       U(5)=1/T/T
 1020: U(3)=1/R/S, U
       (4)=1/R-1/S,
       U(5)=1/T/T
 1025: Q=-1/2
 1030: U(6)=Q*J(U(1
       )*U(3))
 1040: U(7)=U(1)*X(
       1)^2+2*U(6)*
       X(1)*X(3)+U(
       3)*X(3)^2
 1050. U(8)=U(1)*X(
       3)^2+2*U(6)*
       X(3)*X(2)+U(
       3)*X(2)^2
 1060: U(9)=U(1)*X(
       1)*X(3)+U(6)
       *(X(1)*X(2)+
       X(3)^2)+U(3)
       *X(3)*X(2)
 1070: U(10)=U(5)*X
       (4)^2, U(11)=
       U(2)*X(1)+U(
       4)*X(3), U(12
       )=U(2)*X(3)+
       U(4)*X(2)
1080: RETURN
1100: U(1)=U(1)+U(
      1)*X(11), U(2
      )=U(2)+U(1)*
      X(12), U(3)=U
      (3)+U(1)*X(1
      3)
1110: U(4)=U(4)+U(
      1)*X(14), U(5
      )=U(5)+U(1)*
      X(15), U(6)=U
      (6)+U(1)*X(1
      6)
1130: RETURN
1200: A(1)=1/X(10)
      /U(7), A(2)=1
      /X(10)/U(8),
      A(3)=1/X(10)
      /U(10)
1210: A(4)=-U(9)/U
      (7), A(5)=-U(
      9)/U(8), A(6)
      =U(11)/U(7)
1220: A(7)=U(11)/U
      (10), A(8)=U(
      12)/U(8), A(9
      )=U(12)/U(10
      )
1230: FOR J=1TO 6
1235: U(J+12)=U(J)
      /X(10)
1237: U(J+18)=U(J+
      6)*X(10)
1240: NEXT J
1270: RETURN
1300: INPUT "IN-PL
      ANE STRENGTH
      - Y/N?";G$
1330: IF G$="N"
      GOTO 2700
1340: Z=28: U$="MN/
      m": GOSUB 139
      0
1350: GOTO 1420
1390: FOR I=11TO 1
      3
1395: X$=CHR$ Z+
      MID$ (@$(I-2
      ), 2, 1)+" =":
      PRINT USING
      "&&&&&&&&&&&&
      &";X$+"("+U$
```

```
      +")".INPUT @
      (I)
1400: GOSUB AA:
      PRINT X$,@(I
      );U$
1410: NEXT I
      RETURN
1420: X(17)=U(2)*K
      +U(9)*L+U(11
      )*M
1430: X(18)=U(9)*K
      +U(8)*L+U(12
      )*M
1440: X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
1450: FOR I=1TO 6
1460: H$="ANGLE "+
      STR$ (I)+"
      "
1480: USING "&&&&&
      &&&&#####"
1490: IF G$="Y"
      PRINT H$;Y(I
      )
1500: GOSUB 1550
1501: GOSUB 1600
1502: GOSUB 1600
1510: GOSUB 1650
1520: NEXT I
1530: GOTO 2700
1550: Y(I)=-Y(I)
1555: X(23)=(COS Y
      (I))^2: X(24)
      =(SIN Y(I))^
      2, X(25)=COS
      Y(I)*SIN Y(I
      )
1560: X(20)=X(17)*
      X(23)+X(18)*
      X(24)+X(19)*
      X(25)
1570: X(21)=X(17)*
      X(24)+X(18)*
      X(23)+X(19)*
      X(25)
1580: X(22)=2*X(25
      )*(X(18)-X(1
      7))+X(19)*(X
      (23)-X(24))
1585: Y(I)=-Y(I)
1590: RETURN
1600: U(13)=U(2)*X
      (20)^2+2*U(9
      )*X(20)*X(21
      )+U(8)*X(21)
      ^2+U(14)*X(2
      2)^2
1605: U(14)=U(11)*
      X(20)+U(12)*
      X(21)
1610: U(15)=U(14)/
      U(13)/2
1615: U(16)=-U(15)
      +J(U(15)^2+1
      /U(13))
1620: U(17)=U(15)+
      J(U(15)^2+1/
      U(13))
1625: B(1)=INT (X(
      10)/E/U(16)/
      2+1)*2, B(2)=
      INT (X(10)/E
      /U(17)/2+1)*
      2
1630: B(3)=U(16)/X
      (10), B(4)=U(
      17)/X(10)
1635: RETURN
1650: IF G$="N"
      THEN 1685
1653: USING "&&&&&
      #####.####"
1655: PRINT "R+   =
      ";U(16)
1657: IF U$="MN"
      THEN 1665
1660: PRINT "N+   =
      ";B(1)
1665: PRINT "Sgm+=
      ";B(3);"MPa"
1670: PRINT "R-   =
      ";U(17)
1672: IF U$="MN"
      THEN 1680
1675: PRINT "N-   =
      ";B(2)
1680: PRINT "Sgm-=
      ";B(4);"MPa"
1685: RETURN
2550: NEXT J
2680: INPUT "W= ?"
      ;W:GOTO 2655
2700: GOSUB BB
2710: INPUT "FLEX.
       STIFFNESS -
       Y/N?";G$
2720: X$="FLEX. ST
      IFFNESS"
2740: GOSUB 670:
      GOSUB 680
2765: X(10)=Z(0)*E
2770: FOR I=1TO G
2780: GOSUB 700
2785: X(10)=X(10)+
      E*Z(I)
2790: U(I)=2/3*(X(
      10)^3-(X(10)
      -Z(I)*E)^3)
2800: GOSUB 1100
2820: NEXT I
2850: Z=68:TT=0:XX
      =1E6:U$="N.m
      ":IF G$="Y"
      GOSUB 380
2910: GOSUB 800
2930: Z=100:TT=6:X
      X=1E-3:U$=""
      :IF G$="Y"
      GOSUB 380
2934: USING "&&&&&
      &&&&&&&&&&&&
      &"
2935: PRINT "
        m (kN.m)-
      1"
2940: X(10)=2*X(10
      )^3/3
2950: GOSUB 1200
2960: Z=102
2965: INPUT "ENGIN
       FLEX.CST -
      Y/N?";G$
2970: IF G$="Y"
      GOSUB 490
3000: INPUT "NORM.
      FLEX.CST - Y
      /N?";G$
3005: X$="NORMALIZ
      ED CONST"
3010: Z=68:W=1:TT=
      12:XX=1E-3:U
      $="GPa":IF G
      $="Y"GOSUB 6
      30
3050: Z=100:W=2:TT
      =18:XX=1E6:U
      $="TPa-1":IF
      G$="Y"GOSUB
      630
3160: INPUT "  FLE
      XURAL STRENG
      TH - Y/N? ";
      G$
3170: IF G$="N"
      GOTO 3330
3180: Z=72:U$="MN"
      :GOSUB 1390
3200: X(17)=U(2)*K
      +U(9)*L+U(11
      )*M
3210: X(18)=U(9)*K
      +U(8)*L+U(12
      )*M
```

```
3220: USING "&&&&&
      &&&&&&&&###" .
      PRINT H$;X(I
      )
3225. GOSUB 1000
3227. X(I)=Y(I)
3280. GOSUB 1000
3290. X(20)=X(24)*
      A(I),X(21)=X
      (21)*A(I),X(
      22)=X(22)*A(
      I)
3300. GOSUB 1600
3310. GOSUB 1650
3314. NEXT I
3320. X(10)=W
3330. GOTO 3223
3340. END
```

```
3220: X(19)=U(11)*
      K+U(12)*L+U(
      10)*M
3230: A(0)=Z(0)*E
3232: W=X(10)
3235: X(10)=1/6*
      EXP (2/3*LN
      (X(10)*12))
3240. FOR I=1 TO G
3250: A(I)=A(I-1)+
      Z(I)*E
3260: H$="ANGLE "+
      STR$ (I)+"
      "
3268: IF G$="N"
      GOTO 3225
```

SECTION IV

CONCLUSIONS

The description and instruction of the use of Sharp PC-1500 Pocket Computer for the key calculations of the stiffness and strength of symmetric laminated composites are presented in this paper. With the computer packages that were programmed, instant calculations can be made for practical use.

END

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