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TI-59 MAGNETIC CARD CALCULATOR SOLUTIONS TO COMPOSITE MATERIALS--ETC(U)
APR 79 S W TSAI , H T HAHN
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LEVEL II

TI-59 MAGNETIC CARD CALCULATOR SOLUTIONS TO COMPOSITE MATERIALS FORMULAS

MECHANICS AND SURFACE INTERACTIONS BRANCH
NONMETALLIC MATERIALS DIVISION

APRIL 1979

TECHNICAL REPORT AFML-TR-79-4040
Final Report for Period October 1977 to October 1978

AIR FORCE MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

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

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

FOR THE COMMANDER

J. M. KELBLE, Chief
Nonmetallic Materials Division

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Magnetic Card Programs
Composite Materials
Properties of Unidirectional & Laminated Composites
In-Plane and Flexural Stiffness & Strength
Nonmechanical Strains

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

This volume contains the description and instructions of magnetic cards for TI-59 programmable calculators. These tapes contain the key calculations of the stiffness and strength of unidirectional and symmetrically laminated composites. Both in-plane and flexural loadings can be applied. The initial

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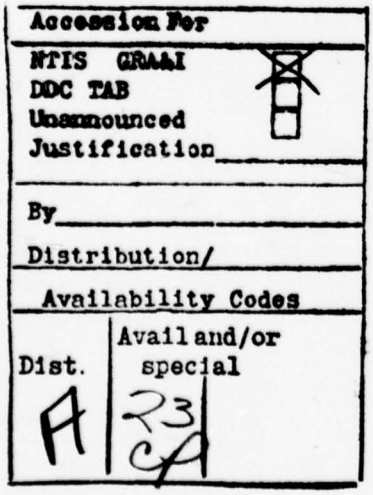
stress and strain due to curing and moisture adsorption are also included in the strength calculation. With the aid of the magnetic cards, instant calculations can be made for practical use. The use of cards is also an effective teaching tool. The formulas used in the cards have been derived in another AFML report, entitled, "Introduction to Composite Materials", AFML-TR-78-201.

FOREWORD

This report was prepared in the Mechanics and Surface Interactions Branch (AFML/MBM), Nonmetallic Materials Division, Air Force Materials Laboratory, Wright-Patterson AFB, Ohio. The work was performed under the support Project No. 2419, "Nonmetallic Structural Materials," Task No. 241903, "Composite Materials and Mechanics Technology." The time period covered by this effort was from October 1977 to October 1978. Stephen W. Tsai (AFML/MBM) was the laboratory project engineer. H. Thomas Hahn was a member of AFML/MBM until 1 August 1978.

The page numbers which appear in the flow charts refer to the pages of this report. The equation number, however, refer to those equations in AFML-TR-78-201, "Introduction to Composite Materials".



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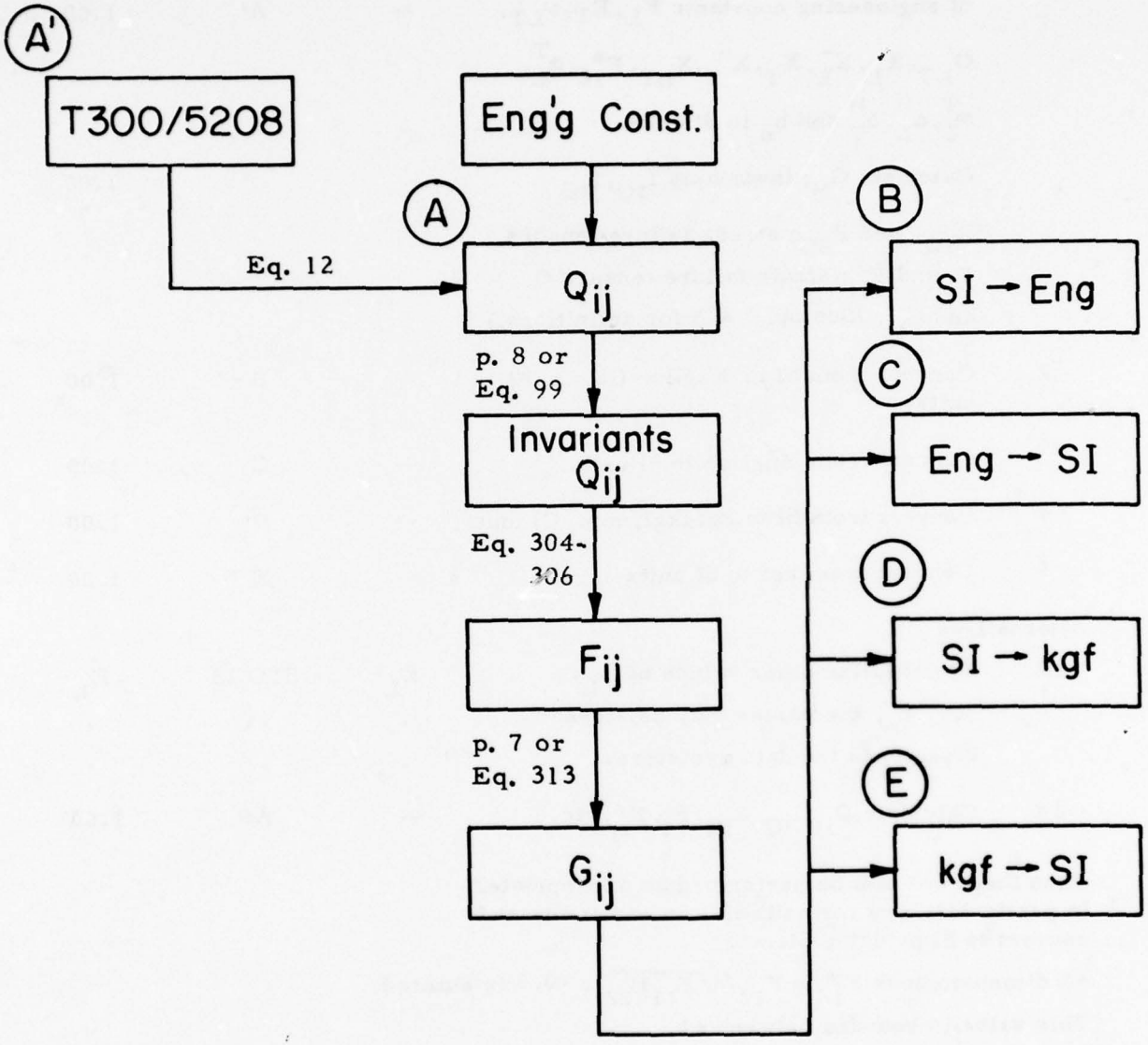
TAPE #1
PROPERTIES OF UNIDIRECTIONAL COMPOSITES



USER INSTRUCTIONS

TAPE #1: PROPERTIES OF UNIDIRECTIONAL COMPOSITES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
1	For T300/5208 plies, initialize values of engineering constants E_L, E_T, ν_{LT},	--	A'	1.00
	$G_{LT}, X_L, X'_L, X_T, X'_T, X_{LT}, F^*_{12}, \alpha^T_L$, $\alpha^T_T, \alpha^H_L, \alpha^H_T$, and h_o in SI units.			
	Calculate Q_{ij}; invariants I_{1Q}, I_{2Q}			1.00
	R_{1Q}, and R_{2Q}; stress failure tensors F_i and F_{ij}; strain failure tensors G_i and G_{ij}. (See pp. 7 & 8 for definitions.)			
2	Convert from SI to English (lb, in, F) units.	--	B	1.00
3	Convert from English to SI units.	--	C	1.00
4	Convert from SI to kgf (kgf, mm, C) units.	--	D	1.00
5	Convert from kgf to SI units	--	E	1.00
Alternatives				
1A	To initialize other values of E_L,	E_L	STO 18	E_L
	..., h_o, the values may be stored	.	.	.
	directly in the data registers.	.	.	.
2A	Calculate $Q_{ij}, I_{iQ}, R_{iQ}, F_i, F_{ij}$, etc.	--	A	1.00

Then Steps 2-5 can be performed as appropriate. In particular, one can initialize in eng. units and convert to SI by using Step 3.

*A dimensionless $F^*_{12} = F_{12}/\sqrt{F_{11}F_{22}} = -0.5$ is entered. This value is bounded between ±1.

Computed ply data should be recorded in blocks 3 and 4 for future use. Tape #1 need not be run, unless a change in unit (e.g. from SI to Eng) or change in properties is desired.

Tape* 1 Title PROPERTIES OF UNIDIRECTIONAL COMPOSITES (T300/5208)

KEYS	STORAGE MEMORIES					
A Initialize(after entering Eng'g Constants)	0		20	ν_{LT}	40	
	1	Q_{11}	21	G_{LT}	41	h_o
A' Initialize T300/5208 (SI)	2	Q_{22}	22	α_L^T	42	I_{1Q}
	3	Q_{12}	23	α_T^T	43	I_{2Q}
B SI (Pa) → English (psi)	4		24	α_L^H	44	R_{1Q}
	5		25	α_T^H	45	R_{2Q}
B'	6		26		46	F_{11}
	7		27	Q_{11}	47	F_1
C Eng (psi) → SI (Pa)	8		28	Q_{22}	48	F_{22}
	9		29	Q_{12}	49	F_2
C'	10		30	Q_{66}	50	$F_{12}^* = F_{12}/\sqrt{F_{11}F_{22}}$
	11		31		51	F_{12}
D SI (Pa) → kgf (kgf/mm^2)	12		32		52	
	13	X_L	33		53	
D'	14	X_L^-	34		54	G_{11}
	15	X_T	35		55	G_{22}
E kgf (kgf/mm^2) → SI (Pa)	16	X_T^-	36		56	G_{12}
	17	X_{LT}	37		57	G_{66}
E'	18	E_L	38		58	G_1
	19	E_T	39	m	59	G_2

T300-5208

```
000  76 LBL
001  16 A'
002  01  1
003  08  8
004  66 PAU
005  57 ENG
006  01  1
007  08  8
008  01  1
009  52 EE
010  09  9
011  42 STO
012  18  18
013  01  1
014  00  0
015  03  3
016  52 EE
017  08  8
018  42 STO
019  19  19
020  93  .
021  02  2
022  08  8
023  42 STO
024  20  20
025  07  7
026  01  1
027  07  7
028  52 EE
029  07  7
030  42 STO
031  21  21
032  01  1
033  05  5
034  52 EE
035  08  8
036  42 STO
037  13  13
038  42 STO
039  14  14
040  04  4
041  52 EE
042  07  7
043  42 STO
044  15  15
045  02  2
046  04  4
047  06  6
048  52 EE
049  06  6
050  42 STO
051  16  16
052  06  6
053  08  8
054  52 EE
055  06  6
056  42 STO
057  17  17
058  93  .
059  05  5
060  94 +/-
061  42, STO
062  50  50
063  01  1
064  52 EE
065  94 +/-
066  08  8
067  42 STO
068  22  22
069  01  1
070  02  2
071  05  5
072  52 EE
073  94 +/-
074  07  7
075  42 STO
076  23  23
077  00  0
078  42 STO
079  24  24
```

```
080  93  .
081  06  6
082  42 STO
083  25  25
084  01  1
085  02  2
086  05  5
087  52 EE
088  94 +/-
089  06  6
090  42 STO
091  41  41
092  76 LBL
093  11  A
```

Q_{ij}

```
094  57 ENG
095  43 RCL
096  20  20
097  33 X²
098  65  ×
099  43 RCL
100  19  19
101  55  ÷
102  43 RCL
103  18  18
104  75  -
105  01  1
106  95  =
107  94 +/-
108  35 1/X
109  42 STO
110  39  39
111  65  ×
112  43 RCL
113  18  18
114  95  =
115  42 STO
116  27  27
117  42 STO
118  01  01
119  43 RCL
120  39  39
121  65  ×
122  43 RCL
123  19  19
124  95  =
125  42 STO
126  28  28
127  42 STO
128  02  02
129  65  ×
130  43 RCL
131  20  20
132  95  =
133  42 STO
134  29  29
135  42 STO
136  03  03
137  43 RCL
138  21  21
139  42 STO
140  30  30
141  65  ×
142  04  4
143  75  -
144  02  2
145  65  ×
146  43 RCL
147  29  29
148  85  +
149  43 RCL
150  27  27
151  85  +
152  43 RCL
153  28  28
154  95  =
155  55  ÷
156  08  8
157  95  =
158  42 STO
159  43  43
```

```
160  75  -
161  43 RCL
162  30  30
163  95  =
164  42 STO
165  45  45
166  43 RCL
167  27  27
168  85  +
169  43 RCL
170  28  28
171  85  +
172  02  2
173  65  ×
174  43 RCL
175  29  29
176  95  =
177  55  ÷
178  04  4
179  95  =
180  42 STO
181  42  42
182  43 RCL
183  27  27
184  75  -
185  43 RCL
186  28  28
187  95  =
188  50 I×I
189  55  ÷
190  02  2
191  95  =
192  42 STO
193  44  44
```

F_{ij}

```
194  43 RCL
195  13  13
196  65  ×
197  43 RCL
198  14  14
199  95  =
200  35 1/X
201  42 STO
202  46  46
203  65  ×
204  43 RCL
205  14  14
206  75  -
207  43 RCL
208  14  14
209  35 1/X
210  95  =
211  42 STO
212  47  47
213  43 RCL
214  15  15
215  65  ×
216  43 RCL
217  16  16
218  95  =
219  35 1/X
220  42 STO
221  48  48
222  65  ×
223  43 RCL
224  46  46
225  95  =
226  34 √X
227  65  ×
228  43 RCL
229  50  50
230  95  =
231  42 STO
232  51  51
233  43 RCL
234  15  15
235  35 1/X
236  75  -
237  43 RCL
238  16  16
239  35 1/X
```

	240	95	=
	241	42	STO
	242	49	49
	243	43	RCL
G_{ij}	244	30	30
	245	55	÷
	246	43	RCL
	247	17	17
	248	95	=
	249	33	X^2
	250	42	STO
	251	57	57
	252	43	RCL
	253	46	46
	254	65	×
	255	43	RCL
	256	27	27
	257	33	X^2
	258	85	+
	259	02	2
	260	65	×
	261	43	RCL
	262	51	51
	263	65	×
	264	43	RCL
	265	27	27
	266	65	×
	267	43	RCL
	268	29	29
	269	85	+
	270	43	RCL
	271	48	48
	272	65	×
	273	43	RCL
	274	29	29
	275	33	X^2
	276	95	=
	277	42	STO
	278	54	54
	279	43	RCL
	280	46	46
	281	65	×
	282	43	RCL
	283	29	29
	284	33	X^2
	285	85	+
	286	02	2
	287	65	×
	288	43	RCL
	289	51	51
	290	65	×
	291	43	RCL
	292	29	29
	293	65	×
	294	43	RCL
	295	28	28
	296	85	+
	297	43	RCL
	298	48	48
	299	65	×
	300	43	RCL
	301	28	28
	302	33	X^2
	303	95	=
	304	42	STO
	305	55	55
	306	43	RCL
	307	46	46
	308	65	×
	309	43	RCL
	310	27	27
	311	65	×
	312	43	RCL
	313	29	29
	314	85	+
	315	43	RCL
	316	51	51
	317	65	×
	318	43	RCL
	319	27	27
	320	65	×
	321	43	RCL
	322	28	28
	323	85	+
	324	43	RCL
	325	51	51
	326	65	×
	327	43	RCL
	328	29	29
	329	33	X^2
	330	85	+
	331	43	RCL
	332	48	48
	333	65	×
	334	43	RCL
	335	28	28
	336	65	×
	337	43	RCL
	338	29	29
	339	95	=
	340	42	STO
	341	56	56
	342	43	RCL
	343	47	47
	344	65	×
	345	43	RCL
	346	27	27
	347	85	+
	348	43	RCL
	349	49	49
	350	65	×
	351	43	RCL
	352	29	29
	353	95	=
	354	42	STO
	355	58	58
	356	43	RCL
	357	47	47
	358	65	×
	359	43	RCL
	360	29	29
	361	85	+
	362	43	RCL
	363	49	49
	364	65	×
	365	43	RCL
	366	28	28
	367	95	=
	368	42	STO
	369	59	59
	370	01	1
	371	95	=
	372	91	R/S
SI →	373	76	LBL
English	374	12	B
	375	06	6
	376	08	8
	377	09	9
	378	05	5
	379	35	1/X
	380	42	STO
	381	40	40
	382	05	5
	383	55	÷
	384	09	9
	385	95	=
	386	49	PRD
	387	22	22
	388	49	PRD
	389	23	23
	390	03	3
	391	09	9
	392	93	.
	393	04	4
	394	49	PRD
	395	41	41
	396	71	SBR
	397	34	FX
Eng→SI	398	76	LBL
	399	13	C
	400	06	6
	401	08	8
	402	09	9
	403	05	5
	404	42	STO
	405	40	40
	406	09	9
	407	55	÷
	408	05	5
	409	95	=
	410	49	PRD
	411	22	22
	412	49	PRD
	413	23	23
	414	03	3
	415	09	9
	416	93	.
	417	04	4
	418	35	1/X
	419	49	PRD
	420	41	41
	421	71	SBR
	422	34	FX
SI → kgf	423	76	LBL
	424	14	D
	425	09	9
	426	08	8
	427	01	1
	428	52	EE
	429	04	4
	430	35	1/X
	431	42	STO
	432	40	40
	433	01	1
	434	52	EE
	435	03	3
	436	49	PRD
	437	41	41
Conver-sion	438	76	LBL
	439	34	FX
	440	43	RCL
	441	40	40
	442	49	PRD
	443	13	13
	444	49	PRD
	445	14	14
	446	49	PRD
	447	15	15
	448	49	PRD
	449	16	16
	450	49	PRD
	451	17	17
	452	49	PRD
	453	18	18
	454	49	PRD
	455	19	19
	456	49	PRD
	457	21	21
	458	61	GTO
	459	00	00
	460	92	92
kgf → SI	461	76	LBL
	462	15	E
	463	09	9
	464	08	8
	465	01	1
	466	52	EE
	467	04	4
	468	42	STO
	469	40	40
	470	01	1
	471	52	EE
	472	03	3
	473	35	1/X
	474	49	PRD
	475	41	41
	476	71	SBR
	477	34	FX
	478	00	0
	479	00	0

T300/5208 SI	T300/5208 ENG.		AS/3501 SI	AS/3501 ENG.	
0. 00	0. 00	00	0. 00	0. 00	00
181. 81114 09	26. 368548 06	01	138. 78041 09	20. 127688 06	01
10. 346159 09	1. 5005306 06	02	9. 0162185 09	1. 3076459 06	02
2. 8969244 09	420. 14858 03	03	2. 7048656 09	392. 29377 03	03
0. 00	0. 00	04	0. 00	0. 00	04
0. 00	0. 00	05	0. 00	0. 00	05
0. 00	0. 00	06	0. 00	0. 00	06
0. 00	0. 00	07	0. 00	0. 00	07
0. 00	0. 00	08	0. 00	0. 00	08
0. 00	0. 00	09	0. 00	0. 00	09
0. 00	0. 00	10	0. 00	0. 00	10
0. 00	0. 00	11	0. 00	0. 00	11
0. 00	0. 00	12	0. 00	0. 00	12
1. 5 09	217. 54895 03	13	1. 44795 09	210. 03	13
1. 5 09	217. 54895 03	14	1. 44795 09	210. 03	14
40. 06	5. 8013053 03	15	51. 7125 06	7. 5 03	15
246. 06	35. 678028 03	16	206. 85 06	30. 03	16
68. 06	9. 862219 03	17	93. 0825 06	13. 5 03	17
181. 09	26. 250906 06	18	137. 96895 09	20. 01 06	18
10. 3 09	1. 4938361 06	19	8. 9635 09	1. 3 06	19
280. -03	280. -03	20	300. -03	300. -03	20
7. 17 09	1. 039884 06	21	7. 10185 09	1. 03 06	21
10. -09	5. 555556 -09	22	10. -09	5. 5555556 -09	22
12. 5-06	6. 9444444 -06	23	12. 5-06	6. 9444444 -06	23
0. 00	0. 00	24	0. 00	0. 00	24
600. -03	600. -03	25	600. -03	600. -03	25
0. 00	0. 00	26	0. 00	0. 00	26
181. 81114 09	26. 368548 06	27	138. 78041 09	20. 127688 06	27
10. 346159 09	1. 5005306 06	28	9. 0162185 09	1. 3076459 06	28
2. 8969244 09	420. 14858 03	29	2. 7048656 09	392. 29377 03	29
7. 17 09	1. 039884 06	30	7. 10185 09	1. 03 06	30
0. 00	0. 00	31	0. 00	0. 00	31
0. 00	0. 00	32	0. 00	0. 00	32
0. 00	0. 00	33	0. 00	0. 00	33
0. 00	0. 00	34	0. 00	0. 00	34
0. 00	0. 00	35	0. 00	0. 00	35
0. 00	0. 00	36	0. 00	0. 00	36
0. 00	0. 00	37	0. 00	0. 00	37
0. 00	0. 00	38	0. 00	0. 00	38
1. 0044814 00	1. 0044814 00	39	1. 0058815 00	1. 0058815 00	39
0. 00	145. 03263 -06	40	6. 895 03	145. 03263-06	40
125. -06	4. 92125 -03	41	133. 24846 -06	5. 2499895-03	41
49. 487787 09	7. 177344 06	42	38. 30159 09	5. 5549804 06	42
26. 880431 09	3. 8985397 06	43	21. 349287 09	3. 0963433 06	43
85. 73249 09	12. 434009 06	44	64. 882096 09	9. 4100211 06	44
19. 710431 09	2. 8586557 06	45	14. 247437 09	2. 0663433 06	45
444. 44444 -21	21. 129344 -12	46	476. 97198 -21	22. 675737 -12	46
0. 00	-1. -18	47	-100. -24	0. 00	47
101. 62602 -18	4. 831405 -09	48	93. 486509 -18	4. 4444444 -09	48
20. 934959 -09	144. 34654 -06	49	14. 503263 -09	100. -06	49
-500. -03	-500. -03	50	-500. -03	-500. -03	50
-3. 3603243 -18	-159. 75326 -12	51	-3. 3388039 -18	-158. 73016 -12	51
0. 00	0. 00	52	0. 00	0. 00	52
0. 00	0. 00	53	0. 00	0. 00	53
12. 004384 03	12. 004384 03	54	7. 3638004 03	7. 3638004 03	54
10. 680652 03	10. 680652 03	55	7. 4403621 03	7. 4403621 03	55
-3. 0691032 03	-3. 0691032 03	56	-1. 7432239 03	-1. 7432239 03	56
11. 117842 03	11. 117842 03	57	5. 8211248 03	5. 8211248 03	57
60. 646995 00	60. 646995 00	58	39. 229377 00	39. 229377 00	58
216. 59641 00	216. 59641 00	59	130. 76459 00	130. 76459 00	59

Q_{ij}

G_{ij}

TAPE #1

TENSOR POLYNOMIAL FAILURE CRITERION IN STRAIN SPACE

Find: $G_{ij}e_ie_j + G_ie_i = 1$

From: $F_{ij}\sigma_i\sigma_j + F_i\sigma_i = 1$

and $\sigma_i = Q_{ij}e_j$

we have $G_{ij} = Q_{ik}Q_{j\ell}F_{k\ell}$

$G_i = Q_{ik}F_k$

For orthotropic materials: $Q_{16} = Q_{26} = 0$

$$G_{11} = F_{11}Q_{11}^2 + 2F_{12}Q_{11}Q_{21} + F_{22}Q_{12}^2$$

$$G_{22} = F_{11}Q_{12}^2 + 2F_{12}Q_{12}Q_{22} + F_{22}Q_{22}^2$$

$$G_{66} = F_{66}Q_{66}^2 = \left(\frac{Q_{66}}{X_{LT}}\right)^2$$

$$G_{12} = F_{11}Q_{11}Q_{12} + F_{12}(Q_{11}Q_{22} + Q_{12}^2) + F_{22}Q_{21}Q_{22}$$

$$G_{16} = G_{26} = 0$$

$$G_1 = F_1Q_{11} + F_2Q_{21}$$

$$G_2 = F_1Q_{12} + F_2Q_{22}$$

$$G_6 = 0$$

TAPE #1

DEFINITIONS OF INVARIANTS OF ELASTIC MODULUS

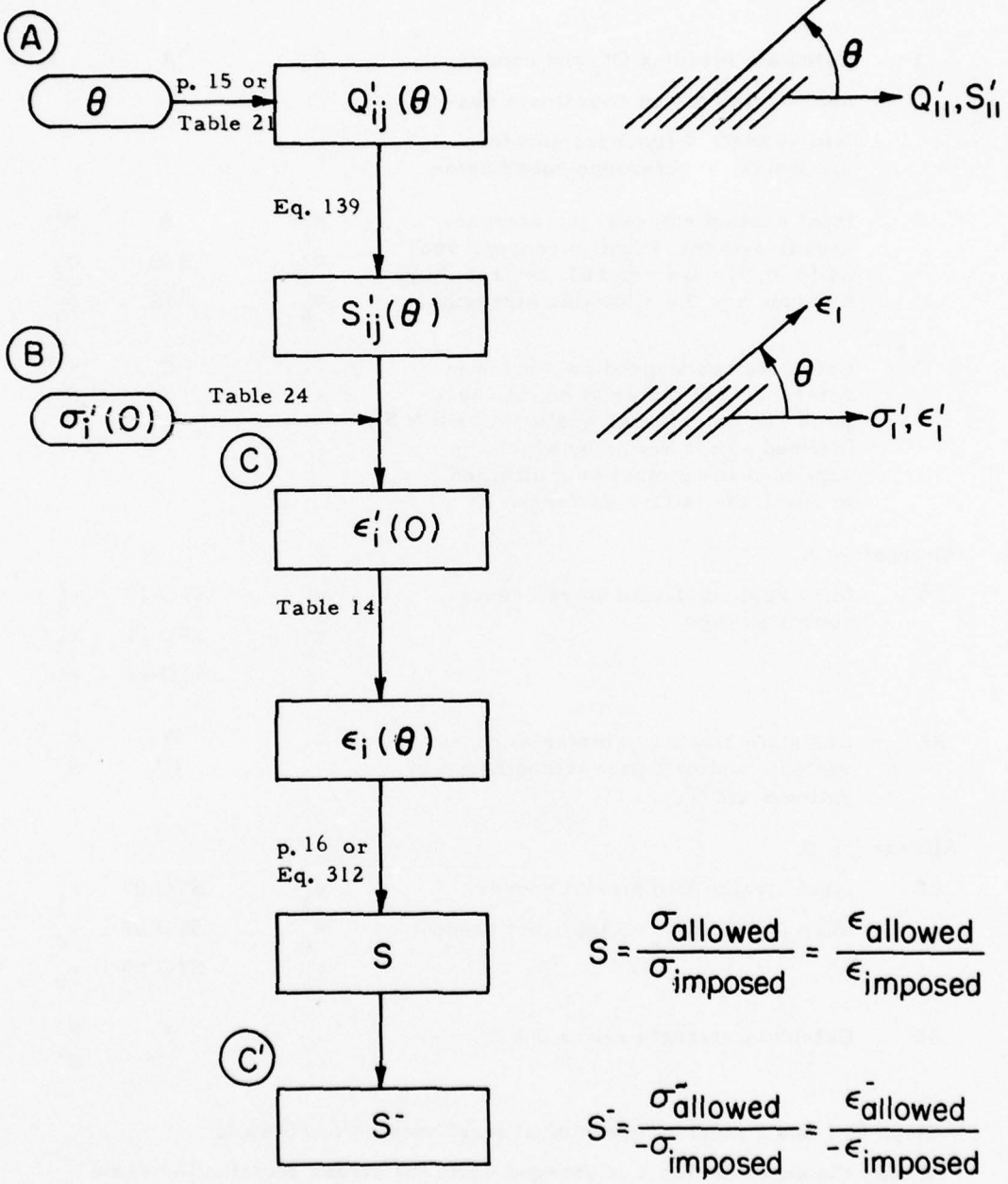
$$I_{1Q} = \frac{1}{2}(Q_{11} + Q_{22} - 2Q_{12}) = (U_1 + U_4) / 2$$

$$I_{2Q} = \frac{1}{4}(Q_{11} + Q_{22} - 2Q_{12} + 4Q_{66}) = U_5 = (U_1 - U_4) / 2$$

$$R_{1Q} = U_2$$

$$R_{2Q} = U_3$$

TAPE #2
OFF-AXIS PROPERTIES OF UNIDIRECTIONAL COMPOSITES



USER INSTRUCTIONS

TAPE #2: OFF-AXIS PROPERTIES OF UNIDIRECTIONAL COMPOSITES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
0	Ply data must be in storage			
1	Calculate modulus Q'_{ij} and compliance S'_{ij} in rotated coordinate system at angle θ (positive counterclockwise) to reference coordinates	θ	A	1.00
2	Input applied stresses in reference coord. system. If unit stresses, such as [1,0,0], are entered, the resulting S values are the allowable strengths.	σ'_1	B	σ'_1
		σ'_2	R/S	σ'_2
		σ'_6	R/S	σ'_6
3*	Calculate corresponding strains in reference and material coord. systems and calculate strength ratios S & S^-. (defined as the ratios by which the applied loading must be multiplied to reach the failure surface).	--	C	S
		--	C'	S^-
Alternative A				
2A	Input applied strains in reference coord. system	ϵ'_1	STO 10	ϵ'_1
		ϵ'_2	STO 11	ϵ'_2
		ϵ'_6	STO 12	ϵ'_6
3A	Calculate strains in material coord. system, and calculate strength-strain ratios S and S^-.	--	D	S
		--	C'	S^-
Alternative B				
2B	Input strains in material coords. (Step 0 needed, but Step 1 not needed)	ϵ_1	STO 07	ϵ_1
		ϵ_2	STO 08	ϵ_2
		ϵ_6	STO 09	ϵ_6
3B	Calculate strength ratios S & S^-.	--	E	S
		--	C'	S^-

* **Steps 0, 1 and 2 must be executed at least once before Step 3. If only the angle in Step 1 is changed while the stress remains the same Step 2 can be skipped. If the stress is changed while the angle remains constant, Step 1 can be omitted.**

Tape* 2 Title OFF-AXIS PROPERTIES OF UNIDIRECTIONAL COMPOSITES

KEYS	STORAGE MEMORIES					
A	0	θ	20		40	4θ
θ	1	σ'_1	21		41	h_o
A'	2	σ'_2	22		42	I_{1Q}
	3	σ'_6	23		43	I_{2Q}
B	4		24		44	R_{1Q}
σ'_i	5		25		45	R_{2Q}
B'	6		26	$\lvert Q \rvert$	46	
	7	ϵ_1	27	Q'_{11}	47	
C	8	ϵ_2	28	Q'_{22}	48	
S	9	ϵ_6	29	Q'_{12}	49	
C'	10	ϵ'_1	30	Q'_{66}	50	
S^-	11	ϵ'_2	31	Q'_{16}	51	
D	12	ϵ'_6	32	Q'_{26}	52	... S
S from ϵ'_i	13		33	S'_{11}	53	... S^-
D'	14		34	S'_{22}	54	G_{11}
	15		35	S'_{12}	55	G_{22}
E	16		36	S'_{66}	56	G_{12}
S from ϵ_i	17		37	S'_{16}	57	G_{66}
E'	18		38	S'_{26}	58	G_1
	19		39	2θ	59	G_2

Tape #2 Off-Axis Properties

θ	000	76	LBL
	001	11	A
	002	57	ENG
	003	42	STO
	004	00	00
	005	65	×
	006	02	2
	007	95	=
	008	42	STO
	009	39	39
	010	65	×
	011	02	2
	012	95	=
	013	42	STO
	014	40	40
	015	01	1
	016	06	6
	017	66	PAU
Q'_{ij}	018	43	RCL
	019	42	42
	020	85	+
	021	43	RCL
	022	43	43
	023	85	+
	024	43	RCL
	025	39	39
	026	39	COS
	027	65	×
	028	43	RCL
	029	44	44
	030	85	+
	031	43	RCL
	032	40	40
	033	39	COS
	034	65	×
	035	43	RCL
	036	45	45
	037	95	=
	038	42	STO
	039	27	27
	040	75	-
	041	43	RCL
	042	39	39
	043	39	COS
	044	65	×
	045	02	2
	046	65	×
	047	43	RCL
	048	44	44
	049	95	=
	050	42	STO
	051	28	28
	052	43	RCL
	053	42	42
	054	75	-
	055	43	RCL
	056	43	43
	057	75	-
	058	43	RCL
	059	40	40
	060	39	COS
	061	65	×
	062	43	RCL
	063	45	45
	064	95	=
	065	42	STO
	066	29	29
	067	85	+
	068	02	2
	069	65	×
	070	43	RCL
	071	43	43
	072	75	-
	073	43	RCL
	074	42	42
	075	95	=
	076	42	STO
	077	30	30
	078	43	RCL
	079	39	39
	080	38	SIN
	081	55	÷
	082	02	2
	083	65	×
	084	43	RCL
	085	44	44
	086	95	=
	087	85	+
	088	43	RCL
	089	40	40
	090	38	SIN
	091	65	×
	092	43	RCL
	093	45	45
	094	95	=
	095	42	STO
	096	31	31
	097	75	-
	098	43	RCL
	099	39	39
	100	38	SIN
	101	65	×
	102	43	RCL
	103	44	44
	104	95	=
	105	94	+/-
	106	42	STO
	107	32	32
$\|Q\|$	108	43	RCL
	109	27	27
	110	65	×
	111	43	RCL
	112	28	28
	113	65	×
	114	43	RCL
	115	30	30
	116	85	+
	117	43	RCL
	118	29	29
	119	65	×
	120	43	RCL
	121	31	31
	122	65	×
	123	43	RCL
	124	32	32
	125	65	×
	126	02	2
	127	75	-
	128	43	RCL
	129	28	28
	130	65	×
	131	43	RCL
	132	31	31
	133	33	X^2
	134	75	-
	135	43	RCL
	136	27	27
	137	65	×
	138	43	RCL
	139	32	32
	140	33	X^2
	141	75	-
	142	43	RCL
	143	30	30
	144	65	×
	145	43	RCL
	146	29	29
	147	33	X^2
	148	95	=
	149	42	STO
	150	26	26
S'^*_{ij}	151	43	RCL
	152	28	28
	153	65	×
	154	43	RCL
	155	30	30
	156	75	-
	157	43	RCL
	158	32	32
	159	33	X^2
	160	95	=
	161	42	STO
	162	33	33
	163	43	RCL
	164	27	27
	165	65	×
	166	43	RCL
	167	28	28
	168	75	-
	169	43	RCL
	170	29	29
	171	33	X^2
	172	95	=
	173	42	STO
	174	36	36
	175	43	RCL
	176	27	27
	177	65	×
	178	43	RCL
	179	30	30
	180	75	-
	181	43	RCL
	182	31	31
	183	33	X^2
	184	95	=
	185	42	STO
	186	34	34
	187	43	RCL
	188	29	29
	189	65	×
	190	43	RCL
	191	32	32
	192	75	-
	193	43	RCL
	194	28	28
	195	65	×
	196	43	RCL
	197	31	31
	198	95	=
	199	42	STO
	200	37	37
	201	43	RCL
	202	31	31
	203	65	×
	204	43	RCL
	205	32	32
	206	75	-
	207	43	RCL
	208	29	29
	209	65	×
	210	43	RCL
	211	30	30
	212	95	=
	213	42	STO
	214	35	35
	215	43	RCL
	216	29	29
	217	65	×
	218	43	RCL
	219	31	31
	220	75	-
	221	43	RCL
	222	27	27
	223	65	×
	224	43	RCL
	225	32	32
	226	95	=
	227	42	STO
	228	38	38
S'_{ij}	229	43	RCL
	230	26	26
	231	35	1/X
	232	49	PRD
	233	33	33
	234	49	PRD
	235	34	34
	236	49	PRD
	237	35	35
	238	49	PRD
	239	36	36

Tape #2 Off-Axis Properties

	240	49	PRD
	241	37	37
	242	49	PRD
	243	38	38
	244	01	1
	245	95	=
	246	91	R/S
σ_i'	247	76	LBL
	248	12	B
	249	42	STO
	250	01	01
	251	91	R/S
	252	42	STO
	253	02	02
	254	91	R/S
	255	42	STO
	256	03	03
	257	91	R/S
ϵ_i'	258	76	LBL
	259	13	C
	260	01	1
	261	04	4
	262	66	PAU
	263	43	RCL
	264	03	03
	265	65	×
	266	43	RCL
	267	37	37
	268	85	+
	269	43	RCL
	270	02	02
	271	65	×
	272	43	RCL
	273	35	35
	274	85	+
	275	43	RCL
	276	01	01
	277	65	×
	278	43	RCL
	279	33	33
	280	95	=
	281	42	STO
	282	10	10
	283	43	RCL
	284	01	01
	285	65	×
	286	43	RCL
	287	35	35
	288	85	+
	289	43	RCL
	290	02	02
	291	65	×
	292	43	RCL
	293	34	34
	294	85	+
	295	43	RCL
	296	03	03
	297	65	×
	298	43	RCL
	299	38	38
	300	95	=
	301	42	STO
	302	11	11
	303	43	RCL
	304	01	01
	305	65	×
	306	43	RCL
	307	37	37
	308	85	+
	309	43	RCL
	310	02	02
	311	65	×
	312	43	RCL
	313	38	38
	314	85	+
	315	43	RCL
	316	03	03
	317	65	×
	318	43	RCL
	319	36	36

	320	95	=
	321	42	STO
	322	12	12
$\epsilon_i(\theta)$	323	76	LBL
	324	14	D
	325	43	RCL
	326	00	00
	327	39	COS
	328	33	X^2
	329	65	×
	330	43	RCL
	331	10	10
	332	85	+
	333	43	RCL
	334	00	00
	335	38	SIN
	336	33	X^2
	337	65	×
	338	43	RCL
	339	11	11
	340	85	+
	341	43	RCL
	342	00	00
	343	39	COS
	344	65	×
	345	43	RCL
	346	00	00
	347	38	SIN
	348	65	×
	349	43	RCL
	350	12	12
	351	95	=
	352	42	STO
	353	07	07
	354	75	-
	355	43	RCL
	356	10	10
	357	75	-
	358	43	RCL
	359	11	11
	360	95	=
	361	94	+/-
	362	42	STO
	363	08	08
	364	43	RCL
	365	11	11
	366	75	-
	367	43	RCL
	368	10	10
	369	95	=
	370	65	×
	371	43	RCL
	372	39	39
	373	38	SIN
	374	85	+
	375	43	RCL
	376	39	39
	377	39	COS
	378	65	×
	379	43	RCL
	380	12	12
	381	95	=
	382	42	STO
	383	09	09
S	384	76	LBL
	385	15	E
	386	43	RCL
	387	54	54
	388	65	×
	389	43	RCL
	390	07	07
	391	33	X^2
	392	85	+
	393	02	2
	394	65	×
	395	43	RCL
	396	56	56
	397	65	×
	398	43	RCL
	399	07	07

	400	65	×
	401	43	RCL
	402	08	08
	403	85	+
	404	43	RCL
	405	55	55
	406	65	×
	407	43	RCL
	408	08	08
	409	33	X^2
	410	85	+
	411	43	RCL
	412	57	57
	413	65	×
	414	43	RCL
	415	09	09
	416	33	X^2
	417	95	=
	418	42	STO
	419	52	52
	420	43	RCL
	421	58	58
	422	65	×
	423	43	RCL
	424	07	07
	425	85	+
	426	43	RCL
	427	59	59
	428	65	×
	429	43	RCL
	430	08	08
	431	95	=
	432	42	STO
	433	53	53
	434	43	RCL
	435	52	52
	436	35	1/X
	437	42	STO
	438	52	52
	439	65	×
	440	43	RCL
	441	53	53
	442	55	÷
	443	02	2
	444	95	=
	445	42	STO
	446	53	53
	447	33	X^2
	448	85	+
	449	43	RCL
	450	52	52
	451	95	=
	452	34	$\sqrt{X}$
	453	42	STO
	454	52	52
	455	85	+
	456	43	RCL
	457	53	53
	458	95	=
	459	94	+/-
	460	42	STO
	461	53	53
	462	85	+
	463	02	2
	464	65	×
	465	43	RCL
	466	52	52
	467	95	=
	468	42	STO
	469	52	52
	470	91	R/S
S'	471	76	LBL
	472	18	C'
	473	43	RCL
	474	53	53
	475	91	R/S
	476	00	0
	477	00	0
	478	00	0
	479	00	0

	θ	0. 00	15. 00		30. 00	45. 00	
σ_i'		1. 00	1. 00	01	1. 00	1. 00	01
		0. 00	0. 00	02	0. 00	0. 00	02
		0. 00	0. 00	03	0. 00	0. 00	03
		0. 00	0. 00	04	0. 00	0. 00	04
		0. 00	0. 00	05	0. 00	0. 00	05
		0. 00	0. 00	06	0. 00	0. 00	06
		5.5248619-12	5.0511395-12	07	3.7569061-12	1.9889503-12	07
		-1.5469613-12	5.0602866-12	08	23.111624-12	47.770209-12	08
		0. 00	-34.867503-12	09	-60.392288-12	-69.735007-12	09
		5.5248619-12	13.768628-12	10	34.746213-12	59.747083-12	10
		-1.5469613-12	-3.657202-12	11	-7.8776833-12	-9.987924-12	11
		0. 00	-30.200717-12	12	-46.957821-12	-45.781258-12	12
		1.5 09	1.5 09	13	1.5 09	1.5 09	13
		1.5 09	1.5 09	14	1.5 09	1.5 09	14
		40. 06	40. 06	15	40. 06	40. 06	15
		246. 06	246. 06	16	246. 06	246. 06	16
		68. 06	68. 06	17	68. 06	68. 06	17
		181. 09	181. 09	18	181. 09	181. 09	18
		10.3 09	10.3 09	19	10.3 09	10.3 09	19
		280. -03	280. -03	20	280. -03	280. -03	20
		7.17 09	7.17 09	21	7.17 09	7.17 09	21
		10. -09	10. -09	22	10. -09	10. -09	22
		12.5-06	12.5-06	23	12.5-06	12.5-06	23
		0. 00	0. 00	24	0. 00	0. 00	24
		600. -03	600. -03	25	600. -03	600. -03	25
		13.426934 30	13.426934 30	26	13.426934 30	13.426934 30	26
Q_{ij}'		181.81114 09	160.46995 09	27	109.37925 09	56.657787 09	27
		10.346159 09	11.976919 09	28	23.646757 09	56.657787 09	28
		2.8969244 09	12.75214 09	29	32.462571 09	42.317787 09	29
		7.17 09	17.025216 09	30	36.735647 09	46.590862 09	30
		0. 00	38.502857 09	31	54.192991 09	42.866245 09	31
		0. 00	4.3633885 09	32	20.053523 09	42.866245 09	32
S_{ij}'		5.5248619-12	13.768628-12	33	34.746213-12	59.747083-12	33
		97.087379-12	93.064094-12	34	80.527471-12	59.747083-12	34
		1.5469613-12	-3.657202-12	35	-7.8776833-12	-9.987924-12	35
		139.47001-12	131.02905-12	36	114.14713-12	105.70616-12	36
		0. 00	-30.200717-12	37	-46.957821-12	-45.781258-12	37
		0. 00	-15.580541-12	38	-32.337645-12	-45.781258-12	38
		0. 00	30. 00	39	60. 00	90. 00	39
		0. 00	60. 00	40	120. 00	180. 00	40
		125. -06	125. -06	41	125. -06	125. -06	41
		49.487787 09	49.487787 09	42	49.487787 09	49.487787 09	42
		26.880431 09	26.880431 09	43	26.880431 09	26.880431 09	43
		85.73249 09	85.73249 09	44	85.73249 09	85.73249 09	44
		19.710431 09	19.710431 09	45	19.710431 09	19.710431 09	45
		444.44444-21	444.44444-21	46	444.44444-21	444.44444-21	46
		0. 00	0. 00	47	0. 00	0. 00	47
		101.62602-18	101.62602-18	48	101.62602-18	101.62602-18	48
		20.934959-09	20.934959-09	49	20.934959-09	20.934959-09	49
		-500. -03	-500. -03	50	-500. -03	-500. -03	50
		-3.3603243-18	-3.3603243-18	51	-3.3603243-18	-3.3603243-18	51
ε		1.5 09	222.22216 06	52	101.22462 06	64.536588 06	52
		1.5 09	322.82798 06	53	215.27228 06	198.9018 06	53
		12.004384 03	12.004384 03	54	12.004384 03	12.004384 03	54
		10.680652 03	10.680652 03	55	10.680652 03	10.680652 03	55
		-3.0691032 03	-3.0691032 03	56	-3.0691032 03	-3.0691032 03	56
		11.117842 03	11.117842 03	57	11.117842 03	11.117842 03	57
		60.646995 00	60.646995 00	58	60.646995 00	60.646995 00	58
		216.59641 00	216.59641 00	59	216.59641 00	216.59641 00	59

TAPE #2

TRANSFORMATION OF MODULUS COMPONENTS

	I_{1Q}	I_{2Q}	R_{1Q}	R_{2Q}
Q'_{11}	1	1	$\cos 2\theta$	$\cos 4\theta$
Q'_{22}	1	1	$-\cos 2\theta$	$\cos 4\theta$
Q'_{12}	1	-1		$-\cos 4\theta$
Q'_{66}		1		$-\cos 4\theta$
Q'_{16}			$\frac{1}{2}\sin 2\theta$	$\sin 4\theta$
Q'_{26}			$\frac{1}{2}\sin 2\theta$	$-\sin 4\theta$

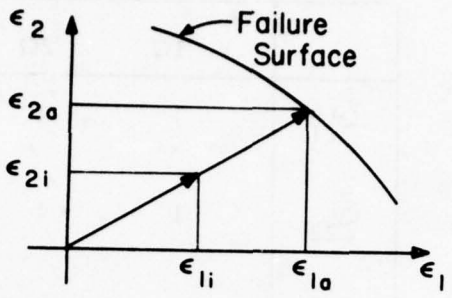
$$Q'_{22} = Q'_{11} - 2R_{1Q}\cos 2\theta$$

$$Q'_{26} = Q'_{16} - 2R_{2Q}\sin 4\theta$$

TAPE #2

STRENGTH RATIOS FOR UNIDIRECTIONAL COMPOSITES

Define $S = \frac{\epsilon_{allowed}}{\epsilon_{imposed}} = \frac{\epsilon_a}{\epsilon_i}$



Proportional loading is assumed; i.e.

$$\frac{\epsilon_{1a}}{\epsilon_{1i}} = \frac{\epsilon_{2a}}{\epsilon_{2i}} = \frac{\epsilon_{6a}}{\epsilon_{6i}} = S$$

Since linearly elastic behavior up to failure is also assumed,

$$S = \frac{\epsilon_a}{\epsilon_i} = \frac{\sigma_{allowed}}{\sigma_{imposed}}$$

Failure occurs when $\epsilon_{imposed} = \epsilon_{allowed}$, the failure criterion is satisfied:

$$G_{ij}\,\epsilon_i\,\epsilon_j + G_i\,\epsilon_i = 1$$

Then strength ratio $S = 1$.

If $\epsilon_{imposed}$ is less than $\epsilon_{allowed}$, $S > 1$. The failure criterion is also satisfied:

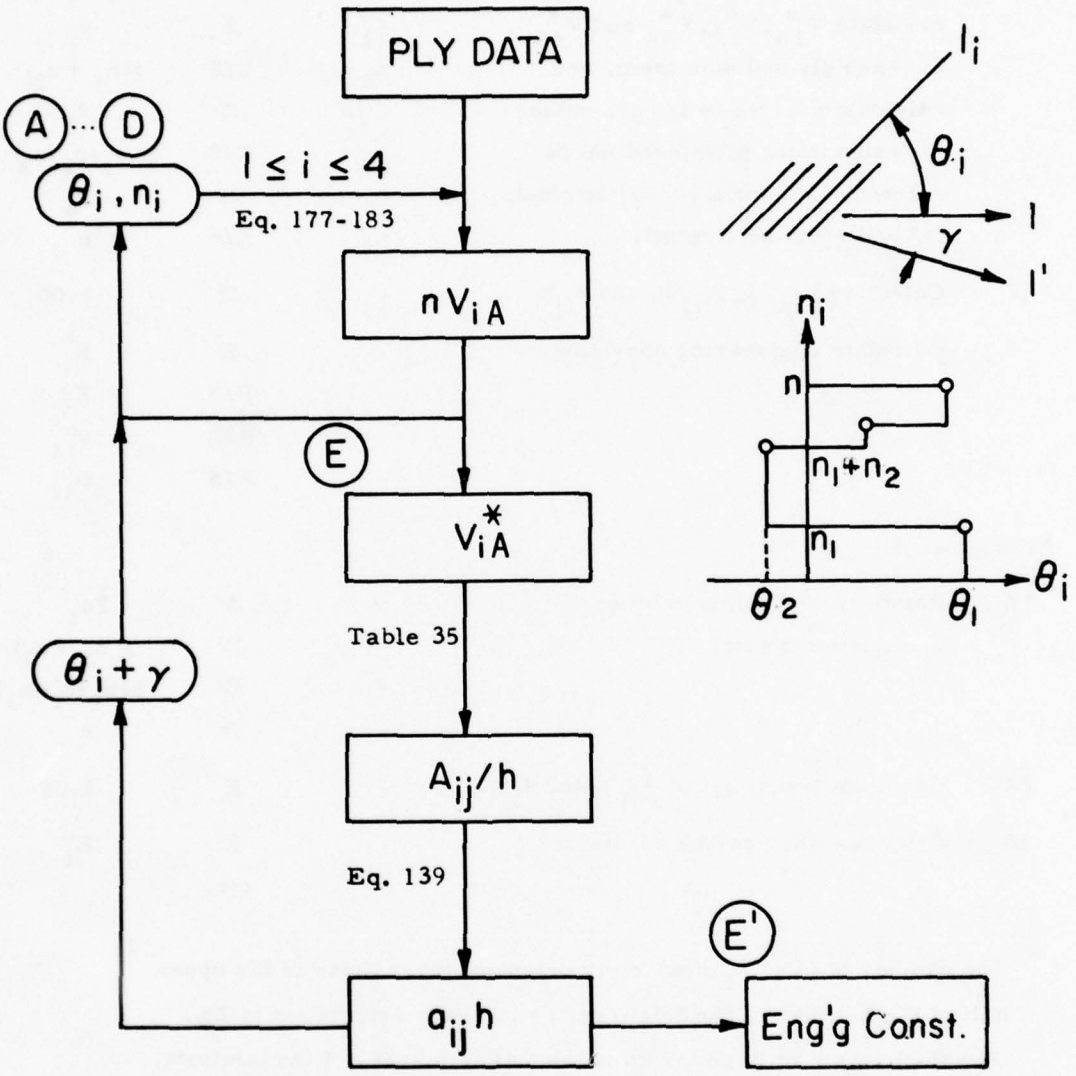
$$G_{ij}\,\epsilon_i\,\epsilon_j\,S^2 + G_i\,\epsilon_i\,S = 1$$

where strains in this equation are $\epsilon_{imposed}$.

For a given state of imposed strains, we can solve for the quadratic equation for S; the other real root is the strength ratio S^- which corresponds to that when all the imposed strains change signs. If original ϵ_i were all positive, the S^- is the strength ratio for opposite strains, or $-\epsilon_i$.

TAPE #3

IN-PLANE STIFFNESS OF SYMMETRIC LAMINATES



USER INSTRUCTIONS

TAPE #3: IN-PLANE STIFFNESS OF SYMMETRIC LAMINATES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
0	Enter ply data.	--		
1	Enter ply angle θ_i, and number of plies at that angle, n_i^*, i=1, 4, and	θ_1	A	θ_1
		n_1	R/S	$2n_1$
	calculate V_{1A}^*, V_{2A}^*, V_{3A}^* and V_{4A}^*	θ_2	B	θ_2
	for each ply and sum them, and	n_2	R/S	$2(n_1 + n_2)$
	calculate n . Since $1 \leq i \leq 4$, values	θ_3	C	θ_3
	for nonexisting plies need not be	n_3	R/S	$2(n_1+n_2+n_3)$
	entered, i.e. for a [0/90] laminate,	θ_4	D	θ_4
	i=3 and 4 can be skipped.	n_4	R/S	n
2	Calculate V_{iA}, h, A_{ij}/h, and $a_{ij}h$.	--	E	1.00
3	Calculate engineering constants	--	E'	E_1^o
		--	R/S	E_2^o
		--	R/S	ν_{12}^o
		--	R/S	G_{12}^o
Alternative A				
1A	Rotate entire laminate by γ; **	γ	A'	$2n_1$
	n_i remain the same	--	B'	$2(n_1 + n_2)$
		--	C'	$2(n_1+n_2+n_3)$
		--	D'	n
2A	Calculate transformed A_{ij}/h and $a_{ij}h$.	--	E	1.00
3A	Calculate engineering constants	--	E'	E_1^o
		--	etc.	

* The number of plies n_i of each ply orientation are those in the upper half of the laminate. The total number for each orientation is $2n_i$. The thickness h in Register 26 is the total thickness of the laminate; the number in Register 46 is one half of the total ply number. For symmetric laminates, only the fraction of each orientation rather than the absolute number of plies is important.

** This is equivalent to rotating the reference coordinates in the clockwise or negative direction.

Tape# 3 Title IN-PLANE STIFFNESS OF SYMMETRIC LAMINATES

KEYS	STORAGE MEMORIES		
A θ_1, n_1	0 γ	20 n_4	40 n_i
	1	21	41 h_o
A' $\theta_1+\gamma$, n_1	2	22	42 I_{1Q}
	3	23	43 I_{2Q}
B θ_2, n_2	4	24	44 R_{1Q}
	5	25	45 R_{2Q}
B' $\theta_2+\gamma$, n_2	6	26 h	46 n/2
	7	27 Q_{11}, A_{11}/h	47 V^*_{1A}
C θ_3, n_3	8	28 Q_{22}, A_{22}/h	48 V^*_{2A}
	9	29 Q_{12}, A_{12}/h	49 V^*_{3A}
C' $\theta_3+\gamma$, n_3	10	30 Q_{66}, A_{66}/h	50 V^*_{4A}
	11	31 A_{16}/h	51
D θ_4, n_4	12	32 A_{26}/h	52
	13 θ_1	33 $a_{11}h$	53
D' $\theta_4+\gamma$, n_4	14 n_1	34 $a_{22}h$	54
	15 θ_2	35 $a_{12}h$	55
E A_{ij}/h, $a_{ij}h$	16 n_2	36 $a_{66}h$	56
	17 θ_3	37 $a_{16}h$	57
E' Engineering Constants	18 n_3	38 $a_{26}h$	58
	19 θ_4	39 θ_i, $\lvert A \rvert$	59

Tape #3 In-Plane Stiffness

θ_1, n_1	000	76	LBL
	001	11	A
	002	57	ENG
	003	42	STO
	004	13	13
	005	00	0
	006	42	STO
	007	46	46
	008	42	STO
	009	47	47
	010	42	STO
	011	48	48
	012	42	STO
	013	49	49
	014	42	STO
	015	50	50
	016	43	RCL
	017	13	13
	018	91	R/S
	019	42	STO
	020	14	14
	021	42	STO
	022	40	40
	023	44	SUM
	024	46	46
	025	43	RCL
	026	13	13
	027	71	SBR
	028	33	X^2
θ_2, n_2	029	76	LBL
	030	12	B
	031	42	STO
	032	15	15
	033	91	R/S
	034	42	STO
	035	16	16
	036	42	STO
	037	40	40
	038	44	SUM
	039	46	46
	040	43	RCL
	041	15	15
	042	71	SBR
	043	33	X^2
θ_3, n_3	044	76	LBL
	045	13	C
	046	42	STO
	047	17	17
	048	91	R/S
	049	42	STO
	050	18	18
	051	42	STO
	052	40	40
	053	44	SUM
	054	46	46
	055	43	RCL
	056	17	17
	057	71	SBR
	058	33	X^2
θ_4, n_4	059	76	LBL
	060	14	D
	061	42	STO
	062	19	19
	063	91	R/S
	064	42	STO
	065	20	20
	066	42	STO
	067	40	40
	068	44	SUM
	069	46	46
	070	43	RCL
	071	19	19
V_{iA}	072	76	LBL
	073	33	X^2
	074	65	×
	075	02	2
	076	95	=
	077	94	+/-
	078	42	STO
	079	39	39
	080	39	COS
	081	65	×
	082	43	RCL
	083	40	40
	084	95	=
	085	44	SUM
	086	47	47
	087	43	RCL
	088	39	39
	089	38	SIN
	090	65	×
	091	43	RCL
	092	40	40
	093	95	=
	094	44	SUM
	095	49	49
	096	02	2
	097	49	PRD
	098	39	39
	099	43	RCL
	100	39	39
	101	39	COS
	102	65	×
	103	43	RCL
	104	40	40
	105	95	=
	106	44	SUM
	107	48	48
	108	43	RCL
	109	39	39
	110	38	SIN
	111	65	×
	112	43	RCL
	113	40	40
	114	95	=
	115	44	SUM
	116	50	50
	117	43	RCL
	118	46	46
	119	65	×
	120	02	2
	121	95	=
	122	91	R/S
V_{iA}^*	123	76	LBL
	124	15	E
	125	01	1
	126	03	3
	127	66	PAU
	128	43	RCL
	129	46	46
	130	35	1/X
	131	49	PRD
	132	47	47
	133	49	PRD
	134	48	48
	135	49	PRD
	136	49	49
	137	49	PRD
	138	50	50
	139	35	1/X
	140	65	×
	141	43	RCL
	142	41	41
	143	65	×
	144	02	2
	145	95	=
	146	42	STO
	147	26	26
A_{ij}/h	148	43	RCL
	149	42	42
	150	85	+
	151	43	RCL
	152	43	43
	153	85	+
	154	43	RCL
	155	47	47
	156	65	×
	157	43	RCL
	158	44	44
	159	85	+
	160	43	RCL
	161	48	48
	162	65	×
	163	43	RCL
	164	45	45
	165	95	=
	166	42	STO
	167	27	27
	168	75	-
	169	02	2
	170	65	×
	171	43	RCL
	172	47	47
	173	65	×
	174	43	RCL
	175	44	44
	176	95	=
	177	42	STO
	178	28	28
	179	43	RCL
	180	42	42
	181	75	-
	182	43	RCL
	183	43	43
	184	75	-
	185	43	RCL
	186	48	48
	187	65	×
	188	43	RCL
	189	45	45
	190	95	=
	191	42	STO
	192	29	29
	193	75	-
	194	43	RCL
	195	42	42
	196	85	+
	197	02	2
	198	65	×
	199	43	RCL
	200	43	43
	201	95	=
	202	42	STO
	203	30	30
	204	43	RCL
	205	49	49
	206	65	×
	207	43	RCL
	208	44	44
	209	55	÷
	210	02	2
	211	85	+
	212	43	RCL
	213	50	50
	214	65	×
	215	43	RCL
	216	45	45
	217	95	=
	218	94	+/-
	219	42	STO
	220	31	31
	221	85	+
	222	02	2
	223	65	×
	224	43	RCL
	225	50	50
	226	65	×
	227	43	RCL
	228	45	45
	229	95	=
	230	42	STO
	231	32	32
|A|	232	43	RCL
	233	27	27
	234	65	×
	235	43	RCL
	236	28	28
	237	65	×
	238	43	RCL
	239	30	30

	240	85	+
	241	43	RCL
	242	29	29
	243	65	×
	244	43	RCL
	245	31	31
	246	65	×
	247	43	RCL
	248	32	32
	249	65	×
	250	02	2
	251	75	-
	252	43	RCL
	253	28	28
	254	65	×
	255	43	RCL
	256	31	31
	257	33	X^2
	258	75	-
	259	43	RCL
	260	27	27
	261	65	×
	262	43	RCL
	263	32	32
	264	33	X^2
	265	75	-
	266	43	RCL
	267	30	30
	268	65	×
	269	43	RCL
	270	29	29
	271	33	X^2
	272	95	=
	273	42	STO
	274	39	39
a_{ij}^*	275	43	RCL
	276	28	28
	277	65	×
	278	43	RCL
	279	30	30
	280	75	-
	281	43	RCL
	282	32	32
	283	33	X^2
	284	95	=
	285	42	STO
	286	33	33
	287	43	RCL
	288	27	27
	289	65	×
	290	43	RCL
	291	28	28
	292	75	-
	293	43	RCL
	294	29	29
	295	33	X^2
	296	95	=
	297	42	STO
	298	36	36
	299	43	RCL
	300	27	27
	301	65	×
	302	43	RCL
	303	30	30
	304	75	-
	305	43	RCL
	306	31	31
	307	33	X^2
	308	95	=
	309	42	STO
	310	34	34
	311	43	RCL
	312	29	29
	313	65	×
	314	43	RCL
	315	32	32
	316	75	-
	317	43	RCL
	318	28	28
	319	65	×

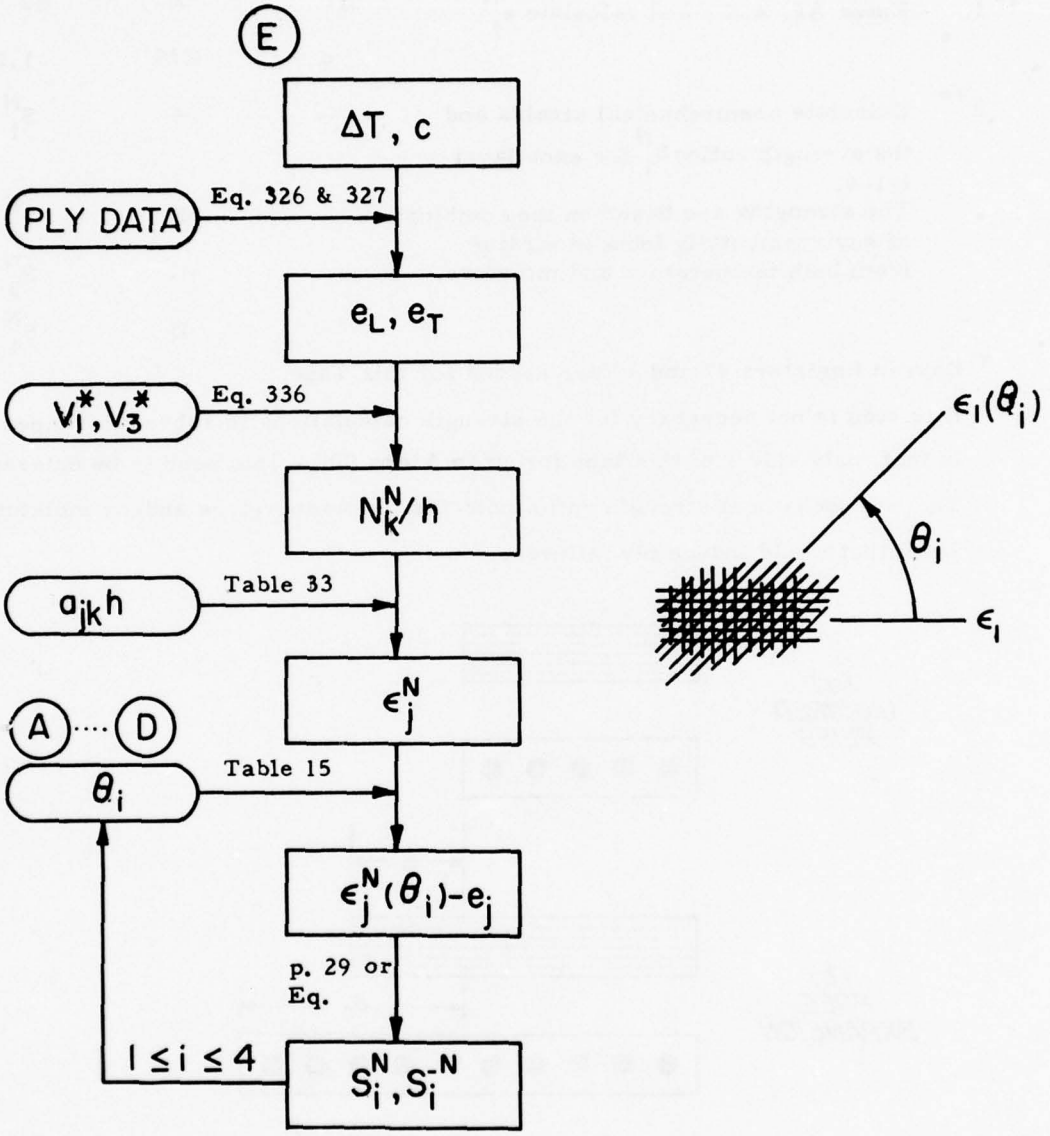
	320	43	RCL
	321	31	31
	322	95	=
	323	42	STO
	324	37	37
	325	43	RCL
	326	31	31
	327	65	×
	328	43	RCL
	329	32	32
	330	75	-
	331	43	RCL
	332	29	29
	333	65	×
	334	43	RCL
	335	30	30
	336	95	=
	337	42	STO
	338	35	35
	339	43	RCL
	340	29	29
	341	65	×
	342	43	RCL
	343	31	31
	344	75	-
	345	43	RCL
	346	27	27
	347	65	×
	348	43	RCL
	349	32	32
	350	95	=
	351	42	STO
	352	38	38
a_{ijh}	353	43	RCL
	354	39	39
	355	35	1/X
	356	49	PRD
	357	33	33
	358	49	PRD
	359	34	34
	360	49	PRD
	361	35	35
	362	49	PRD
	363	36	36
	364	49	PRD
	365	37	37
	366	49	PRD
	367	38	38
	368	01	1
	369	95	=
	370	91	R/S
	371	76	LBL
Eng'g Const.	372	10	E'
	373	43	RCL
	374	33	33
	375	35	1/X
	376	91	R/S
	377	43	RCL
	378	34	34
	379	35	1/X
	380	91	R/S
	381	43	RCL
	382	35	35
	383	55	÷
	384	43	RCL
	385	33	33
	386	95	=
	387	94	+/-
	388	91	R/S
	389	43	RCL
	390	36	36
	391	35	1/X
	392	91	R/S
	393	76	LBL
$\theta_1+\gamma$	394	16	A'
	395	42	STO
	396	00	00
	397	44	SUM
	398	13	13
	399	44	SUM

	400	15	15
	401	44	SUM
	402	17	17
	403	44	SUM
	404	19	19
	405	00	0
	406	42	STO
	407	46	46
	408	42	STO
	409	47	47
	410	42	STO
	411	48	48
	412	42	STO
	413	49	49
	414	42	STO
	415	50	50
	416	43	RCL
	417	14	14
	418	42	STO
	419	40	40
	420	44	SUM
	421	46	46
	422	43	RCL
	423	13	13
	424	71	SBR
	425	33	X^2
$\theta_2+\gamma$	426	76	LBL
	427	17	B'
	428	43	RCL
	429	16	16
	430	42	STO
	431	40	40
	432	44	SUM
	433	46	46
	434	43	RCL
	435	15	15
	436	71	SBR
	437	33	X^2
$\theta_3+\gamma$	438	76	LBL
	439	18	C'
	440	43	RCL
	441	18	18
	442	42	STO
	443	40	40
	444	44	SUM
	445	46	46
	446	43	RCL
	447	17	17
	448	71	SBR
	449	33	X^2
$\theta_4+\gamma$	450	76	LBL
	451	19	D'
	452	43	RCL
	453	20	20
	454	42	STO
	455	40	40
	456	44	SUM
	457	46	46
	458	43	RCL
	459	19	19
	460	71	SBR
	461	33	X^2
	462	00	0
	463	00	0
	464	00	0
	465	00	0
	466	00	0
	467	00	0
	468	00	0
	469	00	0
	470	00	0
	471	00	0
	472	00	0
	473	00	0
	474	00	0
	475	00	0
	476	00	0
	477	00	0
	478	00	0
	479	00	0

Tape #3 In-Plane Stiffness/Sample Problems

	0. 00	00		0. 00	00		0. 00	00		0. 00	00
	181.81114 09	01		181.81114 09	01		181.81114 09	01		181.81114 09	01
	10.346159 09	02		10.346159 09	02		10.346159 09	02		10.346159 09	02
	2.8969244 09	03		2.8969244 09	03		2.8969244 09	03		2.8969244 09	03
	0. 00	04		0. 00	04		0. 00	04		0. 00	04
	0. 00	05		0. 00	05		0. 00	05		0. 00	05
	0. 00	06		0. 00	06		0. 00	06		0. 00	06
	0. 00	07		0. 00	07		0. 00	07		0. 00	07
	0. 00	08		0. 00	08		0. 00	08		0. 00	08
	0. 00	09		0. 00	09		0. 00	09		0. 00	09
	0. 00	10		0. 00	10		0. 00	10		0. 00	10
	0. 00	11		0. 00	11		0. 00	11		0. 00	11
	0. 00	12		0. 00	12		0. 00	12		0. 00	12
θ_i	0. 00	13		45. 00	13		0. 00	13		0. 00	13
	1. 00	14		1. 00	14		1. 00	14		1. 00	14
n_i	90. 00	15		-45. 00	15		60. 00	15		90. 00	15
	1. 00	16		1. 00	16		1. 00	16		1. 00	16
	68. 06	17		68. 06	17		-60. 00	17		45. 00	17
	181. 09	18		181. 09	18		1. 00	18		1. 00	18
	10.3 09	19		10.3 09	19		10.3 09	19		-45. 00	19
	280. -03	20		280. -03	20		280. -03	20		1. 00	20
	7.17 09	21		7.17 09	21		7.17 09	21		7.17 09	21
	10. -09	22		10. -09	22		10. -09	22		10. -09	22
	12.5-06	23		12.5-06	23		12.5-06	23		12.5-06	23
	0. 00	24		0. 00	24		0. 00	24		0. 00	24
	600. -03	25		600. -03	25		600. -03	25		600. -03	25
h	500. -06	26		500. -06	26		750. -06	26		1. -03	26
	96.078649 09	27		56.657787 09	27		76.368218 09	27		76.368218 09	27
	96.078649 09	28		56.657787 09	28		76.368218 09	28		76.368218 09	28
A_{ij}/h	2.8969244 09	29		42.317787 09	29		22.607356 09	29		22.607356 09	29
	7.17 09	30		46.590862 09	30		26.880431 09	30		26.880431 09	30
	0. 00	31		0. 00	31		0. 00	31		0. 00	31
	0. 00	32		0. 00	32		0. 00	32		0. 00	32
	10.417611-12	33		39.919255-12	33		14.352198-12	33		14.352198-12	33
	10.417611-12	34		39.919255-12	34		14.352198-12	34		14.352198-12	34
$a_{ij}h$	-314.10757-15	35		-29.815752-12	35		-4.2486946-12	35		-4.2486946-12	35
	139.47001-12	36		21.463436-12	36		37.201784-12	36		37.201784-12	36
	0. 00	37		0. 00	37		0. 00	37		0. 00	37
	0. 00	38		0. 00	38		0. 00	38		0. 00	38
	66.126864 30	39		66.126864 30	39		143.0311 30	39		143.0311 30	39
	1. 00	40		1. 00	40		1. 00	40		1. 00	40
	125. -06	41		125. -06	41		125. -06	41		125. -06	41
	49.487787 09	42		49.487787 09	42		49.487787 09	42		49.487787 09	42
	26.880431 09	43		26.880431 09	43		26.880431 09	43		26.880431 09	43
	85.73249 09	44		85.73249 09	44		85.73249 09	44		85.73249 09	44
	19.710431 09	45		19.710431 09	45		19.710431 09	45		19.710431 09	45
	2. 00	46		2. 00	46		3. 00	46		4. 00	46
	0. 00	47		0. 00	47		433.33333-15	47		0. 00	47
	1. 00	48		-1. 00	48		-733.33333-15	48		0. 00	48
	0. 00	49		0. 00	49		0. 00	49		0. 00	49
	0. 00	50		0. 00	50		0. 00	50		0. 00	50
	-3.3603243-18	51		-3.3603243-18	51		-3.3603243-18	51		-3.3603243-18	51
	0. 00	52		0. 00	52		0. 00	52		0. 00	52
	0. 00	53		0. 00	53		0. 00	53		0. 00	53
	12.004384 03	54		12.004384 03	54		12.004384 03	54		12.004384 03	54
	10.680652 03	55		10.680652 03	55		10.680652 03	55		10.680652 03	55
	-3.0691032 03	56		-3.0691032 03	56		-3.0691032 03	56		-3.0691032 03	56
	11.117842 03	57		11.117842 03	57		11.117842 03	57		11.117842 03	57
	60.646995 00	58		60.646995 00	58		60.646995 00	58		60.646995 00	58
	216.59641 00	59		216.59641 00	59		216.59641 00	59		216.59641 00	59

TAPE #4
IN-PLANE NON MECHANICAL STRAINS OF SYMMETRIC LAMINATES



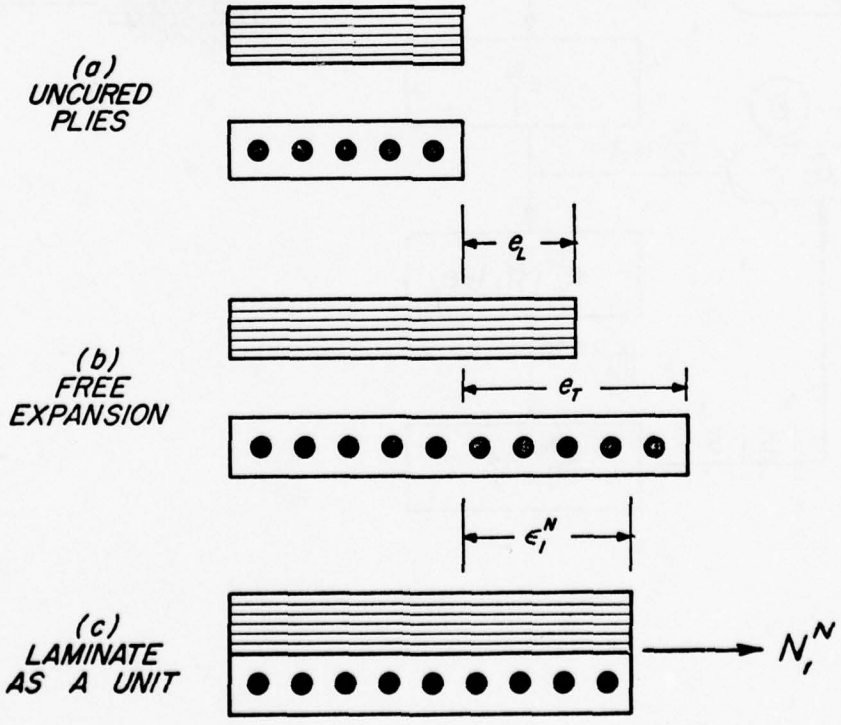
USER INSTRUCTIONS

TAPE #4: IN-PLANE NONMECHANICAL STRAINS OF SYMMETRIC LAMINATES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
0	Data from Tape #3 must be in storage.*	--		--
1	Enter ΔT, and c and calculate ϵ_j^N	ΔT	E	ΔT
		c	R/S	1.00
2**	Calculate nonmechanical strains and the strength ratios S_i^N for each layer, i=1-4.	--	A	S_1^N
	The strengths are based on the combination of environmentally induced strains from both temperature and moisture.	--	B	S_2^N
		--	C	S_3^N
		--	D	S_4^N

* Data in Registers 47 and 49 are needed for this Tape.

** This step is not necessary for the strength calculations in subsequent tapes. In fact, only side 1 of this tape (program steps 000 - 166) need to be entered. The nonmechanical strength ratio indicates the temperature and/or moisture level that would induce ply failures.



Tape* 4 Title IN-PLANE NONMECHANICAL STRAINS OF SYMMETRIC LAMINATES

KEYS	STORAGE MEMORIES					
A S_1^N	0	γ	20	n_4	40	q, ... S_i^N, S_4^N
	1	Q_{11}	21	$2\theta_i$	41	
A'	2	Q_{22}	22	α_L^T	42	I_{1Q}
	3	Q_{12}	23	α_T^T	43	I_{2Q}
B S_2^N	4	N_1^N/h	24	α_L^H	44	R_{1Q}
	5	N_2^N/h	25	α_T^H	45	R_{2Q}
B'	6	N_6^N/h	26	h	46	n
	7	$e_1^N(\theta_i) - e_L$	27	S_1^{-N}	47	V_{1A}^*
C S_3^N	8	$e_2^N(\theta_i) - e_T$	28	S_2^{-N}	48	$V_{2A}^*, \Delta T$
	9	$e_6^N(\theta_i)$	29	S_3^{-N}	49	V_{3A}^*
C'	10	e_1^N	30	S_1^N	50	V_{4A}^*, c
	11	e_2^N	31	S_2^N	51	
D S_4^N	12	e_6^N	32	S_3^N	52	e_L
	13	θ_1	33	a_{11} h	53	e_T
D'	14	n_1	34	a_{22} h	54	G_{11}
	15	θ_2	35	a_{12} h	55	G_{22}
E ΔT, c	16	n_2	36	a_{66} h	56	G_{12}
	17	θ_3	37	a_{16} h	57	G_{66}
E'	18	n_3	38	a_{26} h	58	G_1
	19	θ_4	39	p, |A| ... S_4^{-N}	59	G_2

N_k^N/R

000	76	LBL
001	15	E
002	57	ENG
003	42	STO
004	48	48
005	91	R/S
006	42	STO
007	50	50
008	65	×
009	43	RCL
010	24	24
011	85	+
012	43	RCL
013	48	48
014	65	×
015	43	RCL
016	22	22
017	95	=
018	42	STO
019	52	52
020	08	8
021	66	PAU
022	43	RCL
023	48	48
024	65	×
025	43	RCL
026	23	23
027	85	+
028	43	RCL
029	50	50
030	65	×
031	43	RCL
032	25	25
033	95	=
034	42	STO
035	53	53
036	65	×
037	43	RCL
038	03	03
039	85	+
040	43	RCL
041	52	52
042	65	×
043	43	RCL
044	01	01
045	95	=
046	42	STO
047	39	39
048	43	RCL
049	52	52
050	65	×
051	43	RCL
052	03	03
053	85	+
054	43	RCL
055	53	53
056	65	×
057	43	RCL
058	02	02
059	95	=
060	42	STO
061	40	40
062	85	+
063	43	RCL
064	39	39
065	95	=
066	55	÷
067	02	2
068	95	=
069	42	STO
070	39	39
071	75	-
072	43	RCL
073	40	40
074	95	=
075	42	STO
076	40	40
077	65	×
078	43	RCL
079	47	47

ϵ_j^N

080	85	+
081	43	RCL
082	39	39
083	95	=
084	42	STO
085	04	04
086	75	-
087	02	2
088	65	×
089	43	RCL
090	47	47
091	65	×
092	43	RCL
093	40	40
094	95	=
095	42	STO
096	05	05
097	43	RCL
098	49	49
099	65	×
100	43	RCL
101	40	40
102	95	=
103	94	+/-
104	42	STO
105	06	06
106	65	×
107	43	RCL
108	37	37
109	85	+
110	43	RCL
111	04	04
112	65	×
113	43	RCL
114	33	33
115	85	+
116	43	RCL
117	05	05
118	65	×
119	43	RCL
120	35	35
121	95	=
122	42	STO
123	10	10
124	43	RCL
125	04	04
126	65	×
127	43	RCL
128	35	35
129	85	+
130	43	RCL
131	05	05
132	65	×
133	43	RCL
134	34	34
135	85	+
136	43	RCL
137	06	06
138	65	×
139	43	RCL
140	38	38
141	95	=
142	42	STO
143	11	11
144	43	RCL
145	04	04
146	65	×
147	43	RCL
148	37	37
149	85	+
150	43	RCL
151	05	05
152	65	×
153	43	RCL
154	38	38
155	85	+
156	43	RCL
157	06	06
158	65	×
159	43	RCL

t

160	36	36
161	95	=
162	42	STO
163	12	12
164	01	1
165	95	=
166	91	R/S
167	76	LBL
168	11	A
169	43	RCL
170	13	13
171	71	SBR
172	35	1/X
173	42	STO
174	27	27
175	43	RCL
176	40	40
177	42	STO
178	42	42
179	91	R/S
180	76	LBL
181	12	B
182	43	RCL
183	15	15
184	71	SBR
185	35	1/X
186	42	STO
187	28	28
188	43	RCL
189	40	40
190	42	STO
191	43	43
192	91	R/S
193	76	LBL
194	13	C
195	43	RCL
196	17	17
197	71	SBR
198	35	1/X
199	42	STO
200	29	29
201	43	RCL
202	40	40
203	42	STO
204	44	44
205	91	R/S
206	76	LBL
207	14	D
208	43	RCL
209	19	19
210	71	SBR
211	35	1/X
212	42	STO
213	30	30
214	43	RCL
215	40	40
216	42	STO
217	45	45
218	91	R/S
219	76	LBL
220	35	1/X
221	65	×
222	02	2
223	95	=
224	42	STO
225	21	21
226	01	1
227	00	0
228	66	PAU
229	43	RCL
230	10	10
231	85	+
232	43	RCL
233	11	11
234	95	=
235	55	÷
236	02	2
237	95	=
238	42	STO
239	39	39

S_1^N

S_2^N

S_3^N

S_4^N

$\epsilon_j^N(\theta_i) - e_j$

Tape #4 In-Plane Nonmechanical

240	75	
241	43	RCL
242	11	11
243	95	=
244	42	STO
245	40	40
246	65	×
247	43	RCL
248	21	21
249	39	COS
250	85	+
251	43	RCL
252	39	39
253	85	+
254	53	(
255	43	RCL
256	12	12
257	65	×
258	43	RCL
259	21	21
260	38	SIN
261	54	)
262	55	÷
263	02	2
264	75	-
265	43	RCL
266	52	52
267	95	=
268	42	STO
269	07	07
270	75	-
271	43	RCL
272	10	10
273	75	-
274	43	RCL
275	11	11
276	85	+
277	43	RCL
278	52	52
279	85	+
280	43	RCL
281	53	53
282	95	=
283	94	+/-
284	42	STO
285	08	08
286	43	RCL
287	12	12
288	65	×
289	43	RCL
290	21	21
291	39	COS
292	75	-
293	43	RCL
294	40	40
295	65	×
296	02	2
297	65	×
298	43	RCL
299	21	21
300	38	SIN
301	95	=
302	42	STO
303	09	09
304	33	X^2
305	65	×
306	43	RCL
307	57	57
308	85	+
309	43	RCL
310	54	54
311	65	×
312	43	RCL
313	07	07
314	33	X^2
315	85	+
316	02	2
317	65	×
318	43	RCL
319	56	56
320	65	×
321	43	RCL
322	07	07
323	65	×
324	43	RCL
325	08	08
326	85	+
327	43	RCL
328	55	55
329	65	×
330	43	RCL
331	08	08
332	33	X^2
333	95	=
334	42	STO
335	39	39
336	43	RCL
337	58	58
338	65	×
339	43	RCL
340	07	07
341	85	+
342	43	RCL
343	59	59
344	65	×
345	43	RCL
346	08	08
347	95	=
348	55	÷
349	43	RCL
350	39	39
351	55	÷
352	02	2
353	95	=
354	42	STO
355	40	40
356	33	X^2
357	85	+
358	43	RCL
359	39	39
360	35	1/X
361	95	=
362	34	$\sqrt{X}$
363	42	STO
364	39	39
365	75	-
366	43	RCL
367	40	40
368	95	=
369	42	STO
370	40	40
371	75	-
372	02	2
373	65	×
374	43	RCL
375	39	COS
376	95	=
377	94	+/-
378	92	RTN
379	00	0
380	00	0
381	00	0
382	00	0
383	00	0
384	00	0
385	00	0
386	00	0
387	00	0
388	00	0
389	00	0
390	00	0
391	00	0
392	00	0
393	00	0
394	00	0
395	00	0
396	00	0
397	00	0
398	00	0
399	00	0
400	00	0
401	00	0
402	00	0
403	00	0
404	00	0
405	00	0
406	00	0
407	00	0
408	00	0
409	00	0
410	00	0
411	00	0
412	00	0
413	00	0
414	00	0
415	00	0
416	00	0
417	00	0
418	00	0
419	00	0
420	00	0
421	00	0
422	00	0
423	00	0
424	00	0
425	00	0
426	00	0
427	00	0
428	00	0
429	00	0
430	00	0
431	00	0
432	00	0
433	00	0
434	00	0
435	00	0
436	00	0
437	00	0
438	00	0
439	00	0
440	00	0
441	00	0
442	00	0
443	00	0
444	00	0
445	00	0
446	00	0
447	00	0
448	00	0
449	00	0
450	00	0
451	00	0
452	00	0
453	00	0
454	00	0
455	00	0
456	00	0
457	00	0
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460	00	0
461	00	0
462	00	0
463	00	0
464	00	0
465	00	0
466	00	0
467	00	0
468	00	0
469	00	0
470	00	0
471	00	0
472	00	0
473	00	0
474	00	0
475	00	0
476	00	0
477	00	0
478	00	0
479	00	0

Tape #4 In-Plane Nonmechanical / sample problems

0. 00	00	
181.81114 09	01	
10.346159 09	02	
2.8969244 09	03	
-12.553922 06	04	
-12.553922 06	05	
0. 00	06	
-125.33858-06	07	
1.7481614-03	08	
0. 00	09	
-126.83858-06	10	
-126.83858-06	11	
0. 00	12	
0. 00	13	
1. 00	14	
90. 00	15	
1. 00	16	
68. 06	17	
181. 09	18	
10.3 09	19	
280. -03	20	
180. 00	21	
10. -09	22	
12.5-06	23	
0. 00	24	
600. -03	25	
500. -06	26	
13.092402 00	27	
13.092402 00	28	
2.8969244 09	29	
2.2350152 00	30	
2.2350152 00	31	
0. 00	32	
10.417611-12	33	
10.417611-12	34	
-314.10757-15	35	
139.47001-12	36	
0. 00	37	
0. 00	38	
7.6637088 00	39	
2.2350152 00	40	
125. -06	41	
49.487787 09	42	
26.880431 09	43	
85.73249 09	44	
19.710431 09	45	
2. 00	46	
0. 00	47	
ΔT -150. 00	48	
0. 00	49	
c 0. 00	50	
-3.3603243-18	51	
-1.5-06	52	
-1.875-03	53	
12.004384 03	54	
10.680652 03	55	
-3.0691032 03	56	
11.117842 03	57	
60.646995 00	58	
216.59641 00	59	

0. 00	00	
181.81114 09	01	
10.346159 09	02	
2.8969244 09	03	
19.864625 06	04	
19.864625 06	05	
0. 00	06	
200.7023-06	07	
-2.7992977-03	08	
0. 00	09	
200.7023-06	10	
200.7023-06	11	
0. 00	12	
0. 00	13	
1. 00	14	
90. 00	15	
1. 00	16	
68. 06	17	
181. 09	18	
10.3 09	19	
280. -03	20	
180. 00	21	
10. -09	22	
12.5-06	23	
0. 00	24	
600. -03	25	
500. -06	26	
1.395767 00	27	
1.395767 00	28	
2.8969244 09	29	
8.1762053 00	30	
8.1762053 00	31	
0. 00	32	
10.417611-12	33	
10.417611-12	34	
-314.10757-15	35	
139.47001-12	36	
0. 00	37	
0. 00	38	
4.7859861 00	39	
8.1762053 00	40	
125. -06	41	
49.487787 09	42	
26.880431 09	43	
85.73249 09	44	
19.710431 09	45	
2. 00	46	
0. 00	47	
0. 00	48	
0. 00	49	
5. -03	50	
-3.3603243-18	51	
0. 00	52	
3. -03	53	
12.004384 03	54	
10.680652 03	55	
-3.0691032 03	56	
11.117842 03	57	
60.646995 00	58	
216.59641 00	59	

0. 00	00	
181.81114 09	01	
10.346159 09	02	
2.8969244 09	03	
7.3107032 06	04	
7.3107032 06	05	
0. 00	06	
75.363712-06	07	
-1.0511363-03	08	
0. 00	09	
73.863712-06	10	
73.863712-06	11	
0. 00	12	
0. 00	13	
1. 00	14	
90. 00	15	
1. 00	16	
68. 06	17	
181. 09	18	
10.3 09	19	
280. -03	20	
180. 00	21	
10. -09	22	
12.5-06	23	
0. 00	24	
600. -03	25	
500. -06	26	
3.7170891 00	27	
3.7170891 00	28	
2.8969244 09	29	
21.774182 00	30	
21.774182 00	31	
0. 00	32	
10.417611-12	33	
10.417611-12	34	
-314.10757-15	35	
139.47001-12	36	
0. 00	37	
0. 00	38	
12.745636 00	39	
21.774182 00	40	
125. -06	41	
49.487787 09	42	
26.880431 09	43	
85.73249 09	44	
19.710431 09	45	
2. 00	46	
0. 00	47	
-150. 00	48	
0. 00	49	
5. -03	50	
-3.3603243-18	51	
-1.5-06	52	
1.125-03	53	
12.004384 03	54	
10.680652 03	55	
-3.0691032 03	56	
11.117842 03	57	
60.646995 00	58	
216.59641 00	59	

TAPE #4

STRENGTH RATIOS FOR NONMECHANICAL STRAINS OF LAMINATES

Define $$S^N = \left[\frac{e_{allowed}}{e_{imposed}} \right]^N$$

The strains that must satisfy the failure criterion are

$$e_i\Big]^N_{allowed} = \left[e_i^N - e_i \right]_{all.} = \left\{ \begin{matrix} e_1^N - e_L \\ e_2^N - e_T \\ e_6^N \end{matrix} \right\}_{allowed}$$

where e_i^N = nonmechanical strains

$e_i = \{ e_L , e_T , 0 \}$ = longitudinal, and transverse strains induced by temperature and moisture.

Final failure criterion

$$G_{ij}(e_i^N - e_i)(e_j^N - e_j) + G_i(e_i^N - e_i) = 1$$

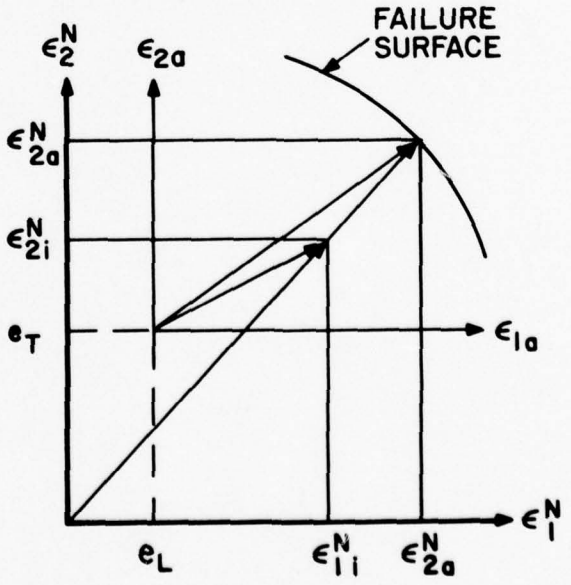
In terms of strength ratio S^N and imposed strain (nonmechanical):

$$G_{ij} S^N(e_i^N - e_i) S^N(e_j^N - e_j) + G_i S^N(e_i^N - e_i) = 1$$

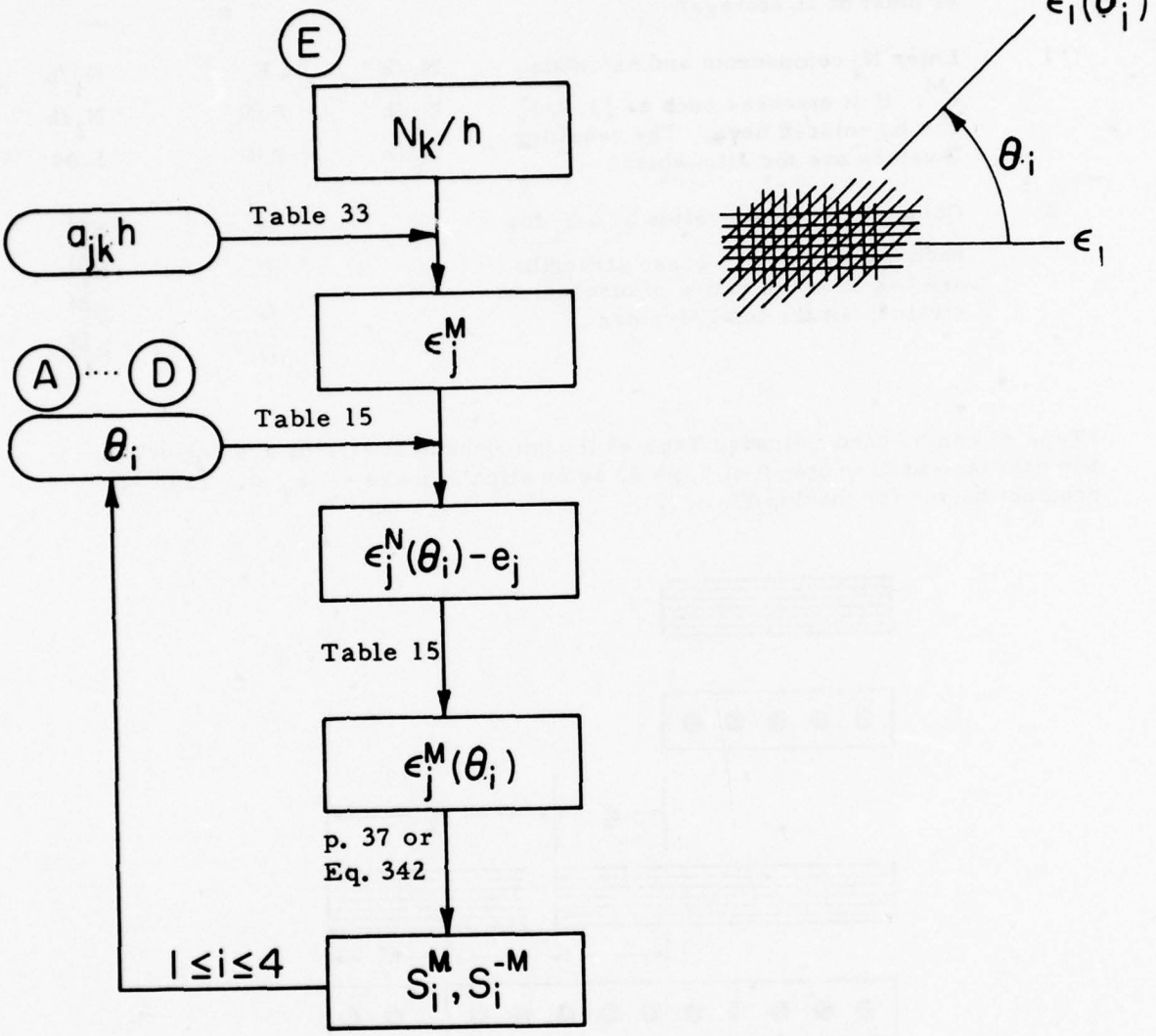
Expand this equation and solve for S^N:

$$a(S^N)^2 + bS^N + c = 0$$

The two roots are S^N and S^{-N}.



TAPE #5
IN-PLANE STRENGTH OF SYMMETRIC LAMINATES

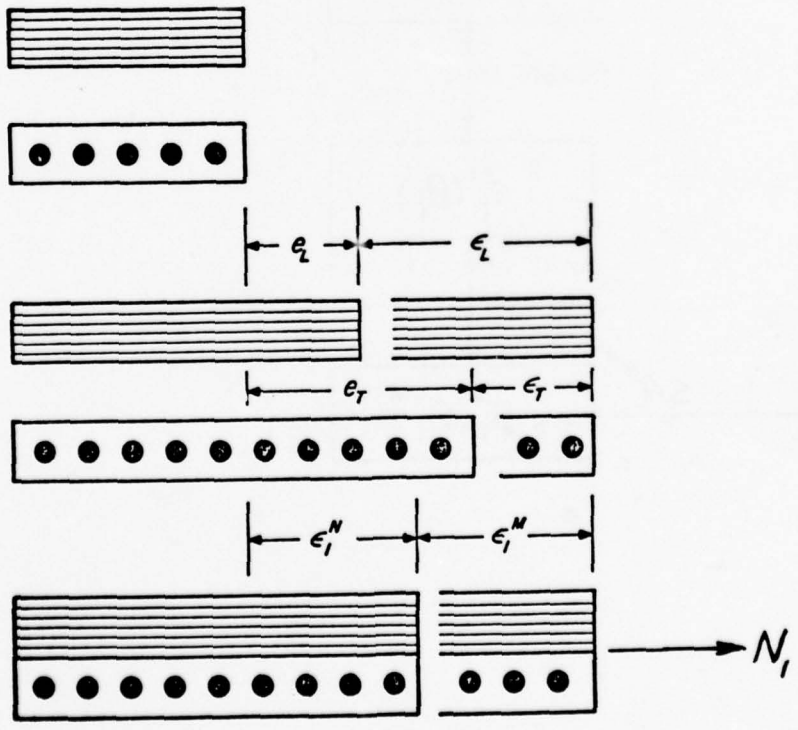


USER INSTRUCTIONS

TAPE #5: IN-PLANE STRENGTH OF SYMMETRIC LAMINATES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
0	Results from Tape #3, or #3 and #4 must be in storage*	--		--
1	Enter N_k components and calculate ϵ_i^M. Unit stresses such as [1,0,0] can be entered here. The resulting S values are the allowables.	N_1/h	E	N_1/h
		N_2/h	R/S	N_2/h
		N_6/h	R/S	1.00
2	Calculate strength ratios S_i & S_i^- for each layer, i=1-4. These strengths are based on the ratios of mechanical strains; not the total strains.	--	A	S_1^M
		--	B	S_2^M
		--	C	S_3^M
		--	D	S_4^M

*Tape #5 can be used following Tape #3 if nonmechanical strains are neglected. Ply data tape used in Step 0 of Tape #3 automatically make $e_L = e_T = 0$. Tape #4 need not be run for making $\Delta T = c = 0$.



Tape* 5 Title IN-PLANE STRENGTH OF SYMMETRIC LAMINATES

KEYS	STORAGE MEMORIES		
A S_1^M	0	20	40
	1 N_1/h	21 $2\theta_i$	41
A'	2 N_2/h	22	42 S_1^M
	3 N_6/h	23	43 S_2^M
B S_2^M	4	24	44 S_3^M
	5	25	45 S_4^M
B'	6	26	46
	7 ϵ_1^M	27 $\epsilon_1^{M(\theta_i)}$	47 S_1^{-M}
C S_3^M	8 ϵ_2^M	28 $\epsilon_2^{M(\theta_i)}$	48 S_2^{-M}
	9 ϵ_6^M	29 $\epsilon_6^{M(\theta_i)}$	49 S_3^{-M}
C'	10 ϵ_1^N	30 $\epsilon_1^{N(\theta_i)}-e_L$	50 S_4^{-M}
	11 ϵ_2^N	31 $\epsilon_2^{N(\theta_i)}-e_T$	51
D S_4^M	12 ϵ_6^N	32 $\epsilon_6^{N(\theta_i)}$	52 e_L
	13 θ_1	33 a_{11}^h	53 e_T
D'	14	34 a_{22}^h	54 G_{11}
	15 θ_2	35 a_{12}^h	55 G_{22}
E N_k/h, ϵ_j^M	16	36 a_{66}^h	56 G_{12}
	17 θ_3	37 a_{16}^h	57 G_{66}
E'	18	38 a_{26}^h	58 G_1
	19 θ_4	39	59 G_2

N_k/R	000	76	LBL
	001	15	E
	002	42	STO
	003	01	01
	004	91	R/S
	005	42	STO
	006	02	02
	007	91	R/S
	008	42	STO
	009	03	03
ϵ_j^M	010	65	×
	011	43	RCL
	012	37	37
	013	85	+
	014	43	RCL
	015	01	01
	016	65	×
	017	43	RCL
	018	33	33
	019	85	+
	020	43	RCL
	021	02	02
	022	65	×
	023	43	RCL
	024	35	35
	025	95	=
	026	42	STO
	027	07	07
	028	43	RCL
	029	01	01
	030	65	×
	031	43	RCL
	032	35	35
	033	85	+
	034	43	RCL
	035	02	02
	036	65	×
	037	43	RCL
	038	34	34
	039	85	+
	040	43	RCL
	041	03	03
	042	65	×
	043	43	RCL
	044	38	38
	045	95	=
	046	42	STO
	047	08	08
	048	43	RCL
	049	01	01
	050	65	×
	051	43	RCL
	052	37	37
	053	85	+
	054	43	RCL
	055	02	02
	056	65	×
	057	43	RCL
	058	38	38
	059	85	+
	060	43	RCL
	061	03	03
	062	65	×
	063	43	RCL
	064	36	36
	065	95	=
	066	42	STO
	067	09	09
	068	01	1
	069	95	=
	070	91	R/S
S_1^M	071	76	LBL
	072	11	A
	073	43	RCL
	074	13	13
	075	71	SBR
	076	35	1/X
	077	42	STO
	078	47	47
	079	43	RCL
	080	40	40
	081	42	STO
	082	42	42
	083	91	R/S
S_2^M	084	76	LBL
	085	12	B
	086	43	RCL
	087	15	15
	088	71	SBR
	089	35	1/X
	090	42	STO
	091	48	48
	092	43	RCL
	093	40	40
	094	42	STO
	095	43	43
	096	91	R/S
S_3^M	097	76	LBL
	098	13	C
	099	43	RCL
	100	17	17
	101	71	SBR
	102	35	1/X
	103	42	STO
	104	49	49
	105	43	RCL
	106	40	40
	107	42	STO
	108	44	44
	109	91	R/S
S_4^M	110	76	LBL
	111	14	D
	112	43	RCL
	113	19	19
	114	71	SBR
	115	35	1/X
	116	42	STO
	117	50	50
	118	43	RCL
	119	40	40
	120	42	STO
	121	45	45
	122	91	R/S
$\epsilon_j^N(\theta_i)$	123	76	LBL
	124	35	1/X
	125	65	×
$-e_j$	126	02	2
	127	95	=
	128	42	STO
	129	21	21
	130	01	1
	131	08	8
	132	66	PAU
	133	43	RCL
	134	10	10
	135	85	+
	136	43	RCL
	137	11	11
	138	95	=
	139	55	÷
	140	02	2
	141	95	=
	142	42	STO
	143	39	39
	144	75	-
	145	43	RCL
	146	11	11
	147	95	=
	148	42	STO
	149	40	40
	150	65	×
	151	43	RCL
	152	21	21
	153	39	COS
	154	85	+
	155	43	RCL
	156	39	39
	157	85	+
	158	43	RCL
	159	12	12
	160	65	×
	161	43	RCL
	162	21	21
	163	38	SIN
	164	55	÷
	165	02	2
	166	75	-
	167	43	RCL
	168	52	52
	169	95	=
	170	42	STO
	171	30	30
	172	75	-
	173	43	RCL
	174	10	10
	175	75	-
	176	43	RCL
	177	11	11
	178	85	+
	179	43	RCL
	180	52	52
	181	85	+
	182	43	RCL
	183	53	53
	184	95	=
	185	94	+/-
	186	42	STO
	187	31	31
	188	43	RCL
	189	12	12
	190	65	×
	191	43	RCL
	192	21	21
	193	39	COS
	194	75	-
	195	43	RCL
	196	40	40
	197	65	×
	198	02	2
	199	65	×
	200	43	RCL
	201	21	21
	202	38	SIN
	203	95	=
	204	42	STO
	205	32	32
$\epsilon_j^M(\theta_i)$	206	43	RCL
	207	07	07
	208	85	+
	209	43	RCL
	210	08	08
	211	95	=
	212	55	÷
	213	02	2
	214	95	=
	215	42	STO
	216	39	39
	217	75	-
	218	43	RCL
	219	08	08
	220	95	=
	221	42	STO
	222	40	40
	223	65	×
	224	43	RCL
	225	21	21
	226	39	COS
	227	85	+
	228	43	RCL
	229	39	39
	230	85	+
	231	43	RCL
	232	09	09
	233	65	×
	234	43	RCL
	235	21	21
	236	38	SIN
	237	55	÷
	238	02	2
	239	95	=

Tape #5 In-Plane Strength

240	42	STO
241	27	27
242	75	-
243	43	RCL
244	07	07
245	75	-
246	43	RCL
247	08	08
248	95	=
249	94	+/-
250	42	STO
251	28	28
252	43	RCL
253	09	09
254	65	×
255	43	RCL
256	21	21
257	39	COS
258	75	-
259	43	RCL
260	40	40
261	65	×
262	02	2
263	65	×
264	43	RCL
265	21	21
266	38	SIN
267	95	=
268	42	STO
269	29	29
270	33	X^2
271	65	×
272	43	RCL
273	57	57
274	85	+
275	43	RCL
276	54	54
277	65	×
278	43	RCL
279	27	27
280	33	X^2
281	85	+
282	02	2
283	65	×
284	43	RCL
285	56	56
286	65	×
287	43	RCL
288	27	27
289	65	×
290	43	RCL
291	28	28
292	85	+
293	43	RCL
294	55	55
295	65	×
296	43	RCL
297	28	28
298	33	X^2
299	95	=
300	42	STO
301	39	39
302	43	RCL
303	58	58
304	65	×
305	43	RCL
306	27	27
307	85	+
308	43	RCL
309	59	59
310	65	×
311	43	RCL
312	28	28
313	85	+
314	02	2
315	65	×
316	53	(
317	43	RCL
318	54	54
319	65	×
320	43	RCL
321	27	27
322	65	×
323	43	RCL
324	30	30
325	85	+
326	43	RCL
327	56	56
328	65	×
329	53	(
330	43	RCL
331	27	27
332	65	×
333	43	RCL
334	31	31
335	85	+
336	43	RCL
337	28	28
338	65	×
339	43	RCL
340	30	30
341	54	)
342	85	+
343	43	RCL
344	55	55
345	65	×
346	43	RCL
347	28	28
348	65	×
349	43	RCL
350	31	31
351	85	+
352	43	RCL
353	57	57
354	65	×
355	43	RCL
356	29	29
357	65	×
358	43	RCL
359	32	32
360	95	=
361	55	÷
362	43	RCL
363	39	39
364	55	÷
365	02	2
366	95	=
367	42	STO
368	40	40
369	01	1
370	75	-
371	43	RCL
372	54	54
373	65	×
374	43	RCL
375	30	30
376	33	X^2
377	75	-
378	02	2
379	65	×
380	43	RCL
381	56	56
382	65	×
383	43	RCL
384	30	30
385	65	×
386	43	RCL
387	31	31
388	75	-
389	43	RCL
390	55	55
391	65	×
392	43	RCL
393	31	31
394	33	X^2
395	75	-
396	43	RCL
397	57	57
398	65	×
399	43	RCL
400	32	32
401	33	X^2
402	75	-
403	43	RCL
404	58	58
405	65	×
406	43	RCL
407	30	30
408	75	-
409	43	RCL
410	59	59
411	65	×
412	43	RCL
413	31	31
414	95	=
415	55	÷
416	43	RCL
417	39	39
418	85	+
419	43	RCL
420	40	40
421	33	X^2
422	95	=
423	34	$\sqrt{X}$
424	42	STO
425	39	39
426	75	-
427	43	RCL
428	40	40
429	95	=
430	42	STO
431	40	40
432	75	-
433	02	2
434	65	×
435	43	RCL
436	39	39
437	95	=
438	94	+/-
439	92	RTN
440	00	0
441	00	0
442	00	0
443	00	0
444	00	0
445	00	0
446	00	0
447	00	0
448	00	0
449	00	0
450	00	0
451	00	0
452	00	0
453	00	0
454	00	0
455	00	0
456	00	0
457	00	0
458	00	0
459	00	0
460	00	0
461	00	0
462	00	0
463	00	0
464	00	0
465	00	0
466	00	0
467	00	0
468	00	0
469	00	0
470	00	0
471	00	0
472	00	0
473	00	0
474	00	0
475	00	0
476	00	0
477	00	0
478	00	0
479	00	0

S_i^M

	0. 00	0. 00 00	0. 00	0. 00 00
N_K	1. 00	1. 00 01	1. 00	1. 00 01
	0. 00	0. 00 02	0. 00	0. 00 02
	0. 00	0. 00 03	0. 00	0. 00 03
	7.3107032 06	0. 00 04	-111.69921 00	0. 00 04
	7.3107032 06	0. 00 05	111.69921 00	0. 00 05
	0. 00	0. 00 06	0. 00	0. 00 06
	10.417611-12	10.417611-12 07	39.919255-12	39.919255-12 07
	-314.10757-15	-314.10757-15 08	-29.815752-12	-29.815752-12 08
	0. 00	0. 00 09	0. 00	0. 00 09
	73.863712-06	0. 00 10	-7.7893455-09	0. 00 10
	73.863712-06	0. 00 11	7.7893455-09	0. 00 11
	0. 00	0. 00 12	0. 00	0. 00 12
	0. 00	0. 00 13	45. 00	45. 00 13
θ_i	1. 00	1. 00 14	1. 00	1. 00 14
n_i	90. 00	90. 00 15	-45. 00	-45. 00 15
	1. 00	1. 00 16	1. 00	1. 00 16
	68. 06	68. 06 17	68. 06	68. 06 17
	181. 09	181. 09 18	181. 09	181. 09 18
	10.3 09	10.3 09 19	10.3 09	10.3 09 19
	280. -03	280. -03 20	280. -03	280. -03 20
	180. 00	180. 00 21	-90. 00	-90. 00 21
	10. -09	10. -09 22	10. -09	10. -09 22
	12.5-06	12.5-06 23	12.5-06	12.5-06 23
	0. 00	0. 00 24	0. 00	0. 00 24
	600. -03	600. -03 25	600. -03	600. -03 25
	500. -06	500. -06 26	500. -06	500. -06 26
	-314.10757-15	-314.10757-15 27	5.0517515-12	5.0517515-12 27
	10.417611-12	10.417611-12 28	5.0517515-12	5.0517515-12 28
	0. 00	0. 00 29	69.735007-12	69.735007-12 29
	75.363712-06	0. 00 30	1.5-06	0. 00 30
	-1.0511363-03	0. 00 31	-1.125-03	0. 00 31
	0. 00	0. 00 32	-15.578691-09	0. 00 32
	10.417611-12	10.417611-12 33	39.919255-12	39.919255-12 33
	10.417611-12	10.417611-12 34	39.919255-12	39.919255-12 34
	-314.10757-15	-314.10757-15 35	-29.815752-12	-29.815752-12 35
	139.47001-12	139.47001-12 36	21.463436-12	21.463436-12 36
	0. 00	0. 00 37	0. 00	0. 00 37
	0. 00	0. 00 38	0. 00	0. 00 38
	1.3193015 09	1.3211072 09 39	150.73203 06	136.08024 06 39
	473.81212 06	373.39552 06 40	138.67287 06	123.2282 06 40
	125. -06	125. -06 41	125. -06	125. -06 41
S_i^M	739.83225 06	681.88201 06 42	138.67287 06	123.2282 06 42
	473.81212 06	373.39552 06 43	138.67287 06	123.2282 06 43
	85.73249 09	85.73249 09 44	85.73249 09	85.73249 09 44
	19.710431 09	19.710431 09 45	19.710431 09	19.710431 09 45
	2. 00	2. 00 46	2. 00	2. 00 46
S_i^{-M}	1.2360994 09	1.1077053 09 47	162.79119 06	148.93229 06 47
	2.1647909 09	2.2688189 09 48	162.79119 06	148.93229 06 48
	0. 00	0. 00 49	0. 00	0. 00 49
	5. -03	0. 00 50	5. -03	0. 00 50
	-3.3603243-18	-3.3603243-18 51	-3.3603243-18	-3.3603243-18 51
	-1.5-06	0. 00 52	-1.5-06	0. 00 52
	1.125-03	0. 00 53	1.125-03	0. 00 53
	12.004384 03	12.004384 03 54	12.004384 03	12.004384 03 54
	10.680652 03	10.680652 03 55	10.680652 03	10.680652 03 55
	-3.0691032 03	-3.0691032 03 56	-3.0691032 03	-3.0691032 03 56
	11.117842 03	11.117842 03 57	11.117842 03	11.117842 03 57
	60.646995 00	60.646995 00 58	60.646995 00	60.646995 00 58
	216.59641 00	216.59641 00 59	216.59641 00	216.59641 00 59

STRENGTH RATIOS FOR MECHANICAL STRAINS OF LAMINATES

Define $$S^M = \frac{e^M_{allowed}}{e^M_{imposed}}$$

The strains that must satisfy the failure criterion are:

$$e_i\Big]_{allowed} = e_i^M\Big]_{allowed} + e_i^N - e_i$$

$$= \begin{Bmatrix} e_1^M + e_1^N - e_L \\ e_2^M + e_2^N - e_T \\ e_6^M + e_6^N \end{Bmatrix}$$

Final failure criterion

$$G_{ij}(e_{ia}^M + e_i^N - e_i)(e_{ja}^M + e_j^N - e_j) + G_i(e_{ia}^M + e_i^N - e_i) = 1$$

In terms of safety factor S^M, and $e^M_{imposed}$

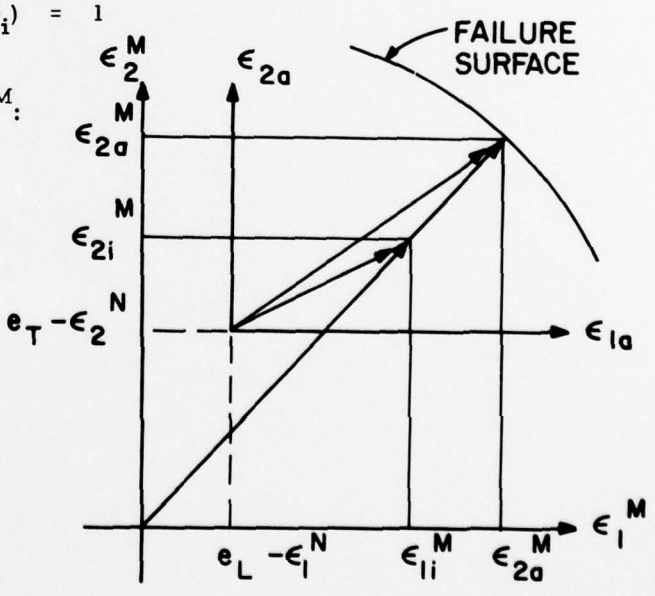
$$G_{ij}(S^M e_i^M + e_i^N - e_i)(S^M e_j^M + e_j^N - e_j)$$

$$+ G_i(S^M e_i^M + e_i^N - e_i) = 1$$

Expand this equation and solve for S^M:

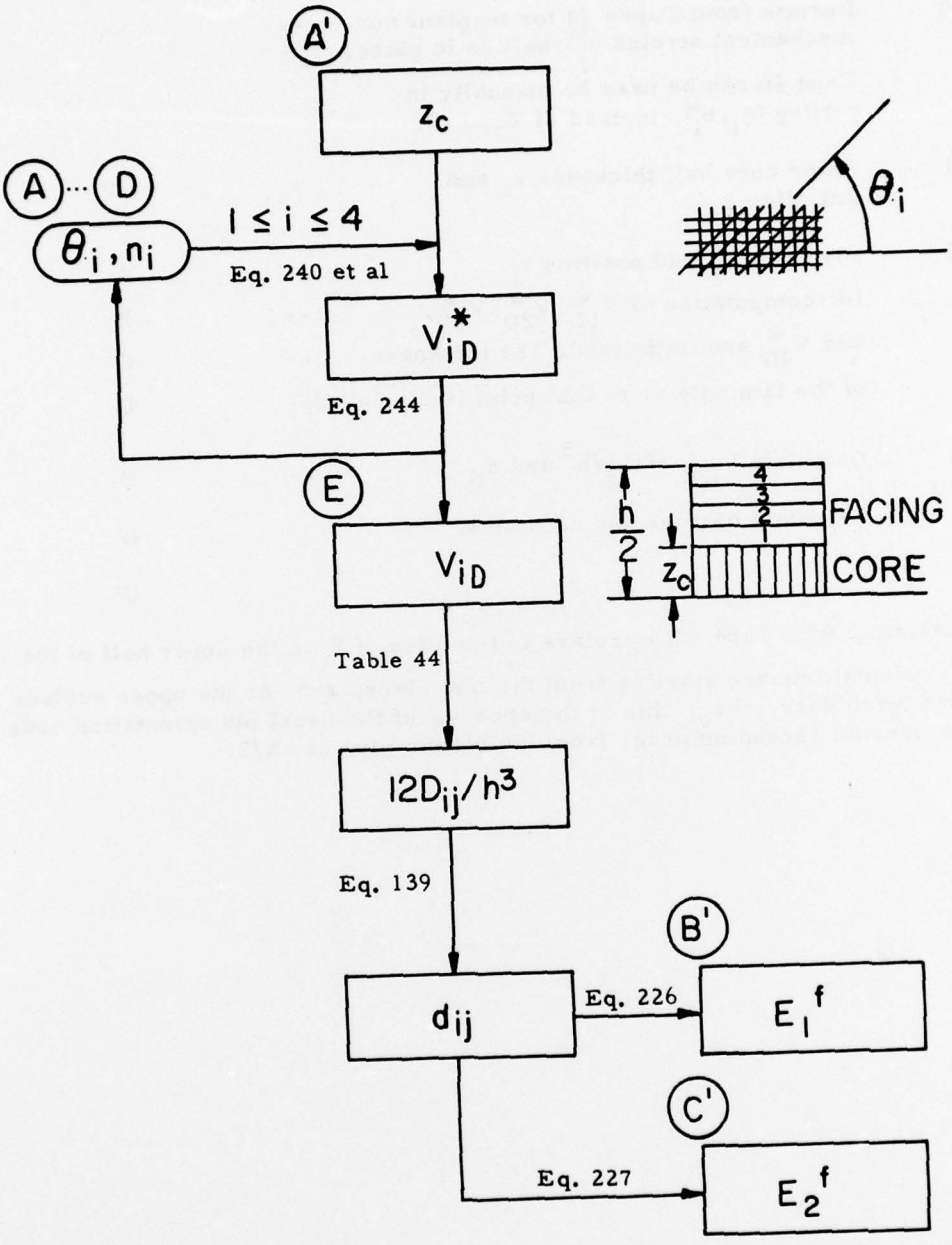
$$a(S^M)^2 + bS^M + c = 0$$

The two roots are S^M and S^{-M}.



TAPE #6

FLEXURAL RIGIDITY OF SYMMETRIC SANDWICH PLATES



USER INSTRUCTIONS

TAPE #6: FLEXURAL RIGIDITY OF SYMMETRIC SANDWICH PLATES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
0	Results from Tapes #4 for in-plane non-mechanical strains e_j^N shall be in place. Tape #6 can be used by manually inputting (θ_i, n_i^*), instead of Tape #3.	--	--	--
1	Enter core half thickness z_c and initialize z_i	z_c	A'	0.00
2	Ply angle θ_i^{**} and position z_i for computation of V_{1D}^*, V_{2D}^*, V_{3D}^*, and V_{4D}^* are initialized. The thickness of the laminate up to that point is displayed.	--	A	$2z_1$
		--	B	$2z_2$
		--	C	$2z_3$
		--	D	$2z_4$
3	Calculate V_{iD}, $12D_{ij}/h^3$ and d_{ij}.	--	E	1.00
4	Calculate engineering constants		B'	E_1^f
			C'	E_2^f

* Consistent with Tape #3, n_i refers to the plies of θ_i in the upper half of the laminate.

** Ply orientations are starting from the mid plane, z=0, or the upper surface of the sandwich core, $z=z_c$; this is the opposite of the usual ply orientation code which uses an ascending order from the bottom ply, $z= -h/2$.

Tape* 6 Title FLEXURAL RIGIDITY OF SYMMETRIC SANDWICH PLATES

KEYS	STORAGE MEMORIES					
A θ_1	0		20	$n_4, z_4 = \frac{h}{2}$	40	
	1		21	z_c	41	h_o
A' z_c, z_i	2		22	V_{1D}	42	I_{1Q}
	3		23	V_{2D}	43	I_{2Q}
B θ_2	4		24	V_{3D}	44	R_{1Q}
	5		25	V_{4D}	45	R_{2Q}
B' E_1^f	6		26		46	$1-\left(\frac{2z_c}{h}\right)^3$
	7		27	$12D_{11}/h^3$	47	
C θ_3	8		28	$12D_{22}/h^3$	48	
	9		29	$12D_{12}/h^3$	49	$2\theta_i$
C' E_2^f	10	e_1^N	30	$12D_{66}/h^3$	50	$z_i^3 - z_{i-1}^3$
	11	e_2^N	31	$12D_{16}/h^3$	51	$h/2, h^3/12$
D θ_4	12	e_6^N	32	$12D_{26}/h^3$	52	e_L
	13	θ_1	33	d_{11}	53	e_T
D'	14	n_1, z_1	34	d_{22}	54	G_{11}
	15	θ_2	35	d_{12}	55	G_{22}
E $12D_{ij}/h^3, d_{ij}$	16	n_2, z_2	36	d_{66}	56	G_{12}
	17	θ_3	37	d_{16}	57	G_{66}
E'	18	n_3, z_3	38	d_{26}	58	G_1
	19	θ_4	39	$\lvert D \rvert$	59	G_2

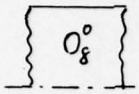
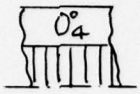
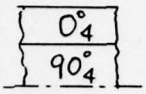
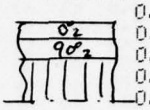
Z_i

	000	76	LBL
	001	16	A'
	002	42	STO
	003	21	21
	004	85	+
	005	43	RCL
	006	14	14
	007	65	×
	008	43	RCL
	009	41	41
	010	95	=
	011	42	STO
	012	14	14
	013	85	+
	014	43	RCL
	015	16	16
	016	65	×
	017	43	RCL
	018	41	41
	019	95	=
	020	42	STO
	021	16	16
	022	85	+
	023	43	RCL
	024	18	18
	025	65	×
	026	43	RCL
	027	41	41
	028	95	=
	029	42	STO
	030	18	18
	031	85	+
	032	43	RCL
	033	20	20
	034	65	×
	035	43	RCL
	036	41	41
	037	95	=
	038	42	STO
	039	20	20
	040	00	0
	041	42	STO
	042	22	22
	043	42	STO
	044	23	23
	045	42	STO
	046	24	24
	047	42	STO
	048	25	25
	049	91	R/S
	050	76	LBL
Z_1	051	11	A
	052	43	RCL
	053	14	14
	054	42	STO
	055	51	51
	056	45	Y^x
	057	03	3
	058	75	-
	059	43	RCL
	060	21	21
	061	45	Y^x
	062	03	3
	063	95	=
	064	42	STO
	065	50	50
	066	43	RCL
	067	13	13
	068	71	SBR
	069	33	X²
	070	76	LBL
Z_2	071	12	B
	072	43	RCL
	073	16	16
	074	42	STO
	075	51	51
	076	45	Y^x
	077	03	3
	078	75	-
	079	43	RCL
	080	14	14
	081	45	Y^x
	082	03	3
	083	95	=
	084	42	STO
	085	50	50
	086	43	RCL
	087	15	15
	088	71	SBR
	089	33	X²
	090	76	LBL
Z_3	091	13	C
	092	43	RCL
	093	18	18
	094	42	STO
	095	51	51
	096	45	Y^x
	097	03	3
	098	75	-
	099	43	RCL
	100	16	16
	101	45	Y^x
	102	03	3
	103	95	=
	104	42	STO
	105	50	50
	106	43	RCL
	107	17	17
	108	71	SBR
	109	33	X²
	110	76	LBL
Z_4	111	14	D
	112	43	RCL
	113	20	20
	114	42	STO
	115	51	51
	116	45	Y^x
	117	03	3
	118	75	-
	119	43	RCL
	120	18	18
	121	45	Y^x
	122	03	3
	123	95	=
	124	42	STO
	125	50	50
	126	43	RCL
	127	19	19
	128	76	LBL
V_{iD}^*	129	33	X²
	130	65	×
	131	02	2
	132	95	=
	133	94	+/-
	134	42	STO
	135	49	49
	136	39	COS
	137	65	×
	138	43	RCL
	139	50	50
	140	95	=
	141	44	SUM
	142	22	22
	143	43	RCL
	144	49	49
	145	38	SIN
	146	65	×
	147	43	RCL
	148	50	50
	149	95	=
	150	44	SUM
	151	24	24
	152	02	2
	153	49	PRD
	154	49	49
	155	43	RCL
	156	49	49
	157	39	COS
	158	65	×
	159	43	RCL
	160	50	50
	161	95	=
	162	44	SUM
	163	23	23
	164	43	RCL
	165	49	49
	166	38	SIN
	167	65	×
	168	43	RCL
	169	50	50
	170	95	=
	171	44	SUM
	172	25	25
	173	43	RCL
	174	51	51
	175	65	×
	176	02	2
	177	95	=
	178	91	R/S
	179	76	LBL
V_{iD}	180	15	E
	181	01	1
	182	03	3
	183	66	PAU
	184	43	RCL
	185	51	51
	186	45	Y^x
	187	03	3
	188	95	=
	189	35	1/X
	190	49	PRD
	191	22	22
	192	49	PRD
	193	23	23
	194	49	PRD
	195	24	24
	196	49	PRD
	197	25	25
	198	65	×
	199	43	RCL
	200	21	21
	201	45	Y^x
	202	03	3
	203	75	-
	204	01	1
	205	95	=
	206	94	+/-
	207	42	STO
	208	46	46
	209	43	RCL
$\frac{12}{h^3} D_{ij}$	210	42	42
	211	85	+
	212	43	RCL
	213	43	43
	214	95	=
	215	65	×
	216	43	RCL
	217	46	46
	218	85	+
	219	43	RCL
	220	22	22
	221	65	×
	222	43	RCL
	223	44	44
	224	85	+
	225	43	RCL
	226	23	23
	227	65	×
	228	43	RCL
	229	45	45
	230	95	=
	231	42	STO
	232	27	27
	233	75	-
	234	02	2
	235	65	×
	236	43	RCL
	237	22	22
	238	65	×
	239	43	RCL

	240	44	44
	241	95	=
	242	42	STO
	243	28	28
	244	43	RCL
	245	42	42
	246	75	-
	247	43	RCL
	248	43	43
	249	95	=
	250	65	×
	251	43	RCL
	252	46	46
	253	75	-
	254	43	RCL
	255	23	23
	256	65	×
	257	43	RCL
	258	45	45
	259	95	=
	260	42	STO
	261	29	29
	262	75	-
	263	43	RCL
	264	42	42
	265	65	×
	266	43	RCL
	267	46	46
	268	85	+
	269	02	2
	270	65	×
	271	43	RCL
	272	43	43
	273	65	×
	274	43	RCL
	275	46	46
	276	95	=
	277	42	STO
	278	30	30
	279	43	RCL
	280	24	24
	281	65	×
	282	43	RCL
	283	44	44
	284	55	÷
	285	02	2
	286	85	+
	287	43	RCL
	288	25	25
	289	65	×
	290	43	RCL
	291	45	45
	292	95	=
	293	94	+/-
	294	42	STO
	295	31	31
	296	85	+
	297	02	2
	298	65	×
	299	43	RCL
	300	25	25
	301	65	×
	302	43	RCL
	303	45	45
	304	95	=
	305	42	STO
	306	32	32
|D|	307	43	RCL
	308	27	27
	309	65	×
	310	43	RCL
	311	28	28
	312	65	×
	313	43	RCL
	314	30	30
	315	85	+
	316	43	RCL
	317	29	29
	318	65	×
	319	43	RCL

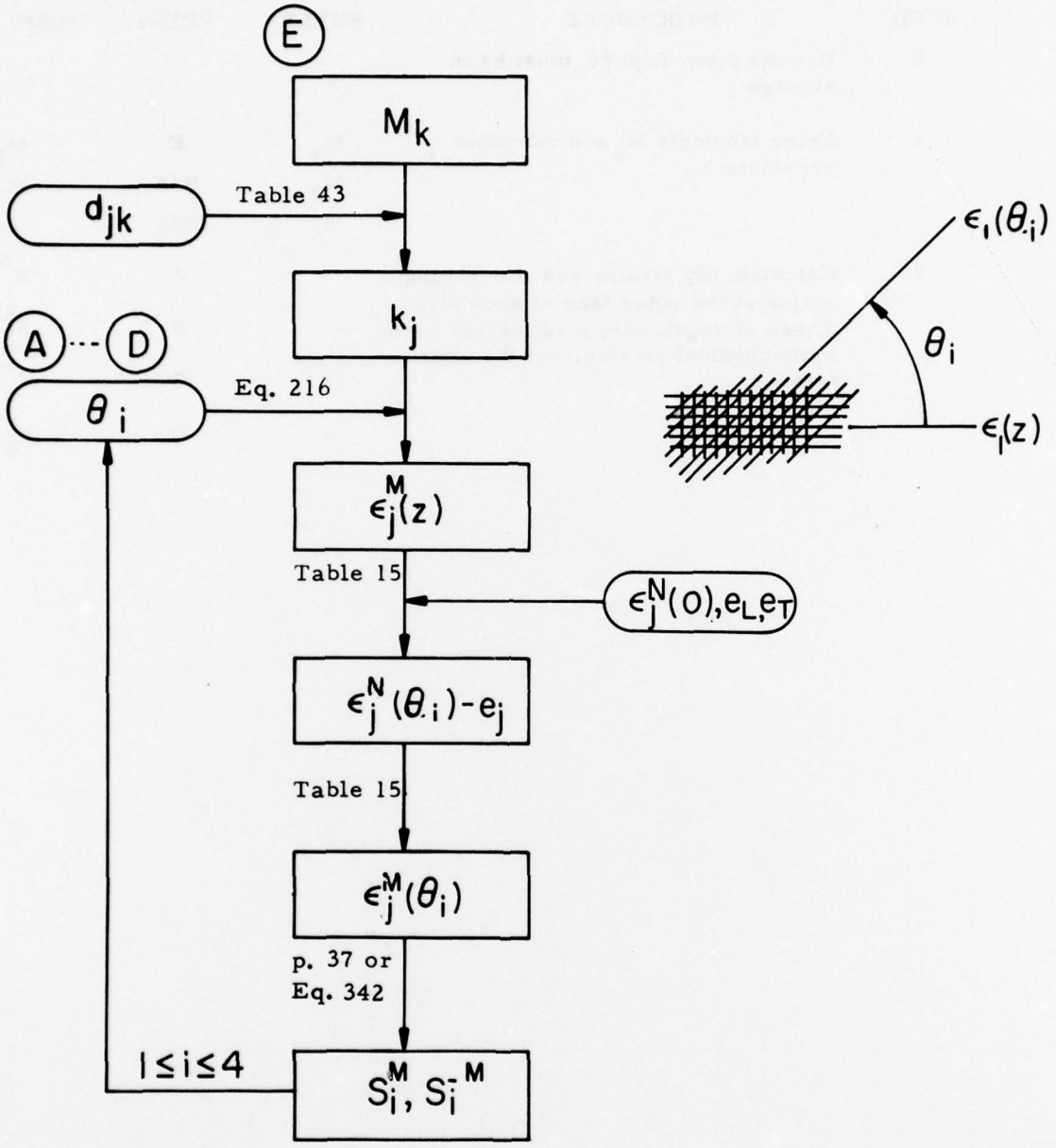
	320	31	31
	321	65	×
	322	43	RCL
	323	32	32
	324	65	×
	325	02	2
	326	75	-
	327	43	RCL
	328	28	28
	329	65	×
	330	43	RCL
	331	31	31
	332	33	X^2
	333	75	-
	334	43	RCL
	335	27	27
	336	65	×
	337	43	RCL
	338	32	32
	339	33	X^2
	340	75	-
	341	43	RCL
	342	30	30
	343	65	×
	344	43	RCL
	345	29	29
	346	33	X^2
	347	95	=
	348	42	STO
	349	39	39
d_{ij}^*	350	43	RCL
	351	28	28
	352	65	×
	353	43	RCL
	354	30	30
	355	75	-
	356	43	RCL
	357	32	32
	358	33	X^2
	359	95	=
	360	42	STO
	361	33	33
	362	43	RCL
	363	27	27
	364	65	×
	365	43	RCL
	366	28	28
	367	75	-
	368	43	RCL
	369	29	29
	370	33	X^2
	371	95	=
	372	42	STO
	373	36	36
	374	43	RCL
	375	27	27
	376	65	×
	377	43	RCL
	378	30	30
	379	75	-
	380	43	RCL
	381	31	31
	382	33	X^2
	383	95	=
	384	42	STO
	385	34	34
	386	43	RCL
	387	29	29
	388	65	×
	389	43	RCL
	390	32	32
	391	75	-
	392	43	RCL
	393	28	28
	394	65	×
	395	43	RCL
	396	31	31
	397	95	=
	398	42	STO
	399	37	37

	400	43	RCL
	401	31	31
	402	65	×
	403	43	RCL
	404	32	32
	405	75	-
	406	43	RCL
	407	29	29
	408	65	×
	409	43	RCL
	410	30	30
	411	95	=
	412	42	STO
	413	35	35
	414	43	RCL
	415	29	29
	416	65	×
	417	43	RCL
	418	31	31
	419	75	-
	420	43	RCL
	421	27	27
	422	65	×
	423	43	RCL
	424	32	32
	425	95	=
	426	42	STO
	427	38	38
d_{ij}	428	43	RCL
	429	51	51
	430	45	Y^X
	431	03	3
	432	65	×
	433	02	2
	434	55	÷
	435	03	3
	436	95	=
	437	42	STO
	438	51	51
	439	65	×
	440	43	RCL
	441	39	39
	442	95	=
	443	35	1/X
	444	49	PRD
	445	33	33
	446	49	PRD
	447	34	34
	448	49	PRD
	449	35	35
	450	49	PRD
	451	36	36
	452	49	PRD
	453	37	37
	454	49	PRD
	455	38	38
	456	01	1
	457	95	=
	458	91	R/S
E_1^f	459	76	LBL
	460	17	B'
	461	43	RCL
	462	33	33
	463	65	×
	464	43	RCL
	465	51	51
	466	95	=
	467	35	1/X
	468	91	R/S
E_2^f	469	76	LBL
	470	18	C'
	471	43	RCL
	472	34	34
	473	65	×
	474	43	RCL
	475	51	51
	476	95	=
	477	35	1/X
	478	91	R/S
	479	00	0

	0. 00	0. 00	0. 00	0. 00 00
	181.81114 09	181.81114 09	181.81114 09	181.81114 09 01
	10.346159 09	10.346159 09	10.346159 09	10.346159 09 02
	2.8969244 09	2.8969244 09	2.8969244 09	2.8969244 09 03
	0. 00	0. 00	0. 00	0. 00 04
	0. 00	 0. 00	 0. 00	 0. 00 05
$[0_8]_s$	0. 00	$[0_4/\text{core}_4]_s$ 0. 00	$[0_4/90_4]_s$ 0. 00	$[0_2/90_2/\text{core}]_s$ 0. 00 06
	0. 00	0. 00	0. 00	0. 00 07
	0. 00	0. 00	0. 00	0. 00 08
	0. 00	0. 00	0. 00	0. 00 09
	0. 00	0. 00	0. 00	0. 00 10
	0. 00	0. 00	0. 00	0. 00 11
	0. 00	0. 00	0. 00	0. 00 12
	0. 00	0. 00	90. 00	90. 00 13
θ_1, z_1	1. -03	1. -03	500. -06	750. -06 14
	40. 06	40. 06	0. 00 θ_2, z_2	0. 00 15
	3.8447501 00	30.750001 03	1. -03	1. -03 16
	68. 06	68. 06	68. 06	68. 06 17
	2.8358135 03	22.65575 06	2.828126 03	22.625 06 18
	10.3 09	10.3 09	10.3 09	10.3 09 19
	5.6677823 03	22.65575 06	5.656251 03	22.625 06 20
z_c	0. 00	500. -06	0. 00	500. -06 21
	1. 00	875. -03	750. -03	281.25-03 22
	1. 00	875. -03	1. 00	875. -03 23
	0. 00	0. 00	0. 00	0. 00 24
	0. 00	0. 00	0. 00	0. 00 25
	0. 00	0. 00	0. 00	0. 00 26
	181.81114 09	159.08475 09	160.37802 09	108.18108 09 27
	10.346159 09	9.0528889 09	31.779281 09	59.956555 09 28
	2.8969244 09	2.5348089 09	2.8969244 09	2.5348089 09 29
$\frac{12D_{ij}}{h^3}$	7.17 09	6.27375 09	7.17 09	6.27375 09 30
	0. 00	0. 00	0. 00	0. 00 31
	0. 00	0. 00	0. 00	0. 00 32
	8.2872928-03	9.4711918-03	9.3683286-03	13.87939-03 33
	145.63107-03	166.43551-03	47.278412-03	25.042923-03 34
d_{ij}	-2.320442-03	-2.6519337-03	-853.99478-06	-586.78489-06 35
	209.20502-03	239.09145-03	209.20502-03	239.09145-03 36
	0. 00	0. 00	0. 00	0. 00 37
	0. 00	0. 00	0. 00	0. 00 38
	13.426934 30	8.9949971 30	36.483153 30	40.652267 30 39
	0. 00	0. 00	0. 00	0. 00 40
	125. -06	125. -06	125. -06	125. -06 41
	49.487787 09	49.487787 09	49.487787 09	49.487787 09 42
	26.880431 09	26.880431 09	26.880431 09	26.880431 09 43
	85.73249 09	85.73249 09	85.73249 09	85.73249 09 44
$1-\left(\frac{2}{3}\right)^3$	19.710431 09	19.710431 09	19.710431 09	19.710431 09 45
	1. 00	875. -03	1. 00	875. -03 46
	0. 00	0. 00	0. 00	0. 00 47
	101.62602-18	101.62602-18	101.62602-18	101.62602-18 48
	0. 00	0. 00	0. 00	0. 00 49
$\frac{h^3}{12}$	1. -09	875. -12	875. -12	578.125-12 50
	666.66667-12	666.66667-12	666.66667-12	666.66667-12 51
	0. 00	0. 00	0. 00	0. 00 52
	0. 00	0. 00	0. 00	0. 00 53
	12.004384 03	12.004384 03	12.004384 03	12.004384 03 54
	10.680652 03	10.680652 03	10.680652 03	10.680652 03 55
	-3.0691032 03	-3.0691032 03	-3.0691032 03	-3.0691032 03 56
	11.117842 03	11.117842 03	11.117842 03	11.117842 03 57
	60.646995 00	60.646995 00	60.646995 00	60.646995 00 58
	216.59641 00	216.59641 00	216.59641 00	216.59641 00 59

TAPE #7

FLEXURAL STRENGTH OF SYMMETRIC SANDWICH PLATES



USER INSTRUCTION

TAPE #7: FLEXURAL STRENGTH OF SYMMETRIC SANDWICH PLATES

STEP	PROCEDURE	ENTER	PRESS	DISPLAY
0	Results from Tape#6 must be in storage	--	--	--
1	Enter Moments M_k and calculate curvature k_j.	M_1	E	M_1
		M_2	R/S	M_2
		M_6	R/S	1.00
2	Calculate ply strains and the strength ratios at the outer face of each ply. These strength-strain ratios are based onmechanical strains, not the total strains.	--	A	S_1^M
		--	B	S_2^M
		--	C	S_3^M
		--	D	S_4^M

Tape# 7 Title FLEXURAL STRENGTH OF SYMMETRIC SANDWICH PLATES

KEYS	STORAGE MEMORIES					
A S_1^M	0		20	z_4	40	$z_i, b, b/2a, S_i$
	1	M_1	21	z_c	41	h_o
A'	2	M_2	22		42	S_1^M
	3	M_6	23		43	S_2^M
B S_2^M	4	k_1	24		44	S_3^M
	5	k_2	25		45	S_4^M
B'	6	k_6	26	M_6	46	$1-\left(\frac{2z_c}{h}\right)^3$
	7	$\epsilon_1^{M(z)}$	27	$\epsilon_1^{M(\theta_i)}$	47	S_1^{-M}
C S_3^M	8	$\epsilon_2^{M(z)}$	28	$\epsilon_2^{M(\theta_i)}$	48	S_2^{-M}
	9	$\epsilon_6^{M(z)}$	29	$\epsilon_6^{M(\theta_i)}$	49	S_3^{-M}
C'	10	ϵ_1^N	30	$\epsilon_1^{N(\theta_i)} - e_L$	50	θ_i, S_4^{-M}
	11	ϵ_2^N	31	$\epsilon_2^{N(\theta_i)} - e_T$	51	$h/2, h^3/12$
D S_4^M	12	ϵ_6^N	32	$\epsilon_6^{N(\theta_i)}$	52	e_L
	13	θ_1	33	d_{11}	53	e_T
D'	14	z_1	34	d_{22}	54	G_{11}
	15	θ_2	35	d_{12}	55	G_{22}
E M_k	16	z_2	36	d_{66}	56	G_{12}
	17	θ_3	37	d_{16}	57	G_{66}
E'	18	z_3	38	d_{26}	58	G_1
	19	θ_4	39	$D, a, 1/a, \sqrt{\ }, S_i^-$	59	G_2

M_k	000	76	LBL
	001	15	E
	002	42	STO
	003	01	01
	004	91	R/S
	005	42	STO
	006	02	02
	007	91	R/S
	008	42	STO
	009	03	03
k_j	010	65	×
	011	43	RCL
	012	37	37
	013	85	+
	014	43	RCL
	015	01	01
	016	65	×
	017	43	RCL
	018	33	33
	019	85	+
	020	43	RCL
	021	02	02
	022	65	×
	023	43	RCL
	024	35	35
	025	95	=
	026	42	STO
	027	04	04
	028	43	RCL
	029	01	01
	030	65	×
	031	43	RCL
	032	35	35
	033	85	+
	034	43	RCL
	035	02	02
	036	65	×
	037	43	RCL
	038	34	34
	039	85	+
	040	43	RCL
	041	03	03
	042	65	×
	043	43	RCL
	044	38	38
	045	95	=
	046	42	STO
	047	05	05
	048	43	RCL
	049	01	01
	050	65	×
	051	43	RCL
	052	37	37
	053	85	+
	054	43	RCL
	055	02	02
	056	65	×
	057	43	RCL
	058	38	38
	059	85	+
	060	43	RCL
	061	03	03
	062	65	×
	063	43	RCL
	064	36	36
	065	95	=
	066	42	STO
	067	06	06
	068	01	1
	069	95	=
	070	91	R/S
S_1^M	071	76	LBL
	072	11	A
	073	43	RCL
	074	13	13
	075	42	STO
	076	50	50
	077	43	RCL
	078	14	14
	079	71	SBR
	080	35	1/X
	081	42	STO
	082	47	47
	083	43	RCL
	084	40	40
	085	42	STO
	086	42	42
	087	91	R/S
S_2^M	088	76	LBL
	089	12	B
	090	43	RCL
	091	15	15
	092	42	STO
	093	50	50
	094	43	RCL
	095	16	16
	096	71	SBR
	097	35	1/X
	098	42	STO
	099	48	48
	100	43	RCL
	101	40	40
	102	42	STO
	103	43	43
	104	91	R/S
S_3^M	105	76	LBL
	106	13	C
	107	43	RCL
	108	17	17
	109	42	STO
	110	50	50
	111	43	RCL
	112	18	18
	113	71	SBR
	114	35	1/X
	115	42	STO
	116	49	49
	117	43	RCL
	118	40	40
	119	42	STO
	120	44	44
	121	91	R/S
S_4^M	122	76	LBL
	123	14	D
	124	43	RCL
	125	19	19
	126	42	STO
	127	50	50
	128	43	RCL
	129	20	20
	130	71	SBR
	131	35	1/X
	132	42	STO
	133	50	50
	134	43	RCL
	135	40	40
	136	42	STO
	137	45	45
	138	91	R/S
$\epsilon_j^M(z_i)$	139	76	LBL
	140	35	1/X
	141	42	STO
	142	40	40
	143	65	×
	144	43	RCL
	145	04	04
	146	95	=
	147	42	STO
	148	07	07
	149	01	1
	150	09	9
	151	66	PAU
	152	43	RCL
	153	40	40
	154	65	×
	155	43	RCL
	156	05	05
	157	95	=
	158	42	STO
	159	08	08
	160	43	RCL
	161	40	40
	162	65	×
	163	43	RCL
	164	06	06
	165	95	=
	166	42	STO
	167	09	09
$\epsilon_j^N(\theta_i) - e_j$	168	02	2
	169	49	PRD
	170	50	50
	171	43	RCL
	172	10	10
	173	85	+
	174	43	RCL
	175	11	11
	176	95	=
	177	55	-
	178	02	2
	179	95	=
	180	42	STO
	181	39	39
	182	75	-
	183	43	RCL
	184	11	11
	185	95	=
	186	42	STO
	187	40	40
	188	65	×
	189	43	RCL
	190	50	50
	191	39	COS
	192	85	+
	193	43	RCL
	194	39	39
	195	85	+
	196	43	RCL
	197	12	12
	198	65	×
	199	43	RCL
	200	50	50
	201	38	SIN
	202	55	÷
	203	02	2
	204	75	-
	205	43	RCL
	206	52	52
	207	95	=
	208	42	STO
	209	30	30
	210	75	-
	211	02	2
	212	65	×
	213	43	RCL
	214	39	39
	215	85	+
	216	43	RCL
	217	52	52
	218	85	+
	219	43	RCL
	220	53	53
	221	95	=
	222	94	+/-
	223	42	STO
	224	31	31
	225	43	RCL
	226	12	12
	227	65	×
	228	43	RCL
	229	50	50
	230	39	COS
	231	75	-
	232	43	RCL
	233	40	40
	234	65	×
	235	02	2
	236	65	×
	237	43	RCL
	238	50	50
	239	38	SIN

Tape #7 Flexural Strength

	240 95 =		
	241 42 STO		
	242 32 32		
$\epsilon_j^M(\theta_i)$	243 43 RCL		
	244 07 07		
	245 85 +		
	246 43 RCL		
	247 08 08		
	248 95 =		
	249 55 ÷		
	250 02 2		
	251 95 =		
	252 42 STO		
	253 39 39		
	254 75 -		
	255 43 RCL		
	256 08 08		
	257 95 =		
	258 42 STO		
	259 40 40		
	260 65 ×		
	261 43 RCL		
	262 50 50		
	263 39 COS		
	264 85 +		
	265 43 RCL		
	266 39 39		
	267 85 +		
	268 43 RCL		
	269 09 09		
	270 65 ×		
	271 43 RCL		
	272 50 50		
	273 38 SIN		
	274 55 ÷		
	275 02 2		
	276 95 =		
	277 42 STO		
	278 27 27		
	279 75 -		
	280 43 RCL		
	281 07 07		
	282 75 -		
	283 43 RCL		
	284 08 08		
	285 95 =		
	286 94 +/-		
	287 42 STO		
	288 28 28		
	289 43 RCL		
	290 09 09		
	291 65 ×		
	292 43 RCL		
	293 50 50		
	294 39 COS		
	295 75 -		
	296 43 RCL		
	297 40 40		
	298 65 ×		
	299 02 2		
	300 65 ×		
	301 43 RCL		
	302 50 50		
	303 38 SIN		
	304 95 =		
	305 42 STO		
	306 29 29		
S_i^M	307 33 X^2		
	308 65 ×		
	309 43 RCL		
	310 57 57		
	311 85 +		
	312 43 RCL		
	313 54 54		
	314 65 ×		
	315 43 RCL		
	316 27 27		
	317 33 X^2		
	318 85 +		
	319 02 2		
	320 65 ×		
	321 43 RCL		
	322 56 56		
	323 65 ×		
	324 43 RCL		
	325 27 27		
	326 65 ×		
	327 43 RCL		
	328 28 28		
	329 85 +		
	330 43 RCL		
	331 55 55		
	332 65 ×		
	333 43 RCL		
	334 28 28		
	335 33 X^2		
	336 95 =		
	337 42 STO		
	338 39 39		
	339 43 RCL		
	340 58 58		
	341 65 ×		
	342 43 RCL		
	343 27 27		
	344 85 +		
	345 43 RCL		
	346 59 59		
	347 65 ×		
	348 43 RCL		
	349 28 28		
	350 85 +		
	351 02 2		
	352 65 ×		
	353 53 (		
	354 43 RCL		
	355 54 54		
	356 65 ×		
	357 43 RCL		
	358 27 27		
	359 65 ×		
	360 43 RCL		
	361 30 30		
	362 85 +		
	363 43 RCL		
	364 56 56		
	365 65 ×		
	366 53 (		
	367 43 RCL		
	368 27 27		
	369 65 ×		
	370 43 RCL		
	371 31 31		
	372 85 +		
	373 43 RCL		
	374 28 28		
	375 65 ×		
	376 43 RCL		
	377 30 30		
	378 54)		
	379 85 +		
	380 43 RCL		
	381 55 55		
	382 65 ×		
	383 43 RCL		
	384 28 28		
	385 65 ×		
	386 43 RCL		
	387 31 31		
	388 85 +		
	389 43 RCL		
	390 57 57		
	391 65 ×		
	392 43 RCL		
	393 29 29		
	394 65 ×		
	395 43 RCL		
	396 32 32		
	397 95 =		
	398 55 ÷		
	399 43 RCL		
	400 39 39		
	401 55 ÷		
	402 02 2		
	403 95 =		
	404 42 STO		
	405 40 40		
	406 01 1		
	407 75 -		
	408 43 RCL		
	409 54 54		
	410 65 ×		
	411 43 RCL		
	412 30 30		
	413 33 X^2		
	414 75 -		
	415 02 2		
	416 65 ×		
	417 43 RCL		
	418 56 56		
	419 65 ×		
	420 43 RCL		
	421 30 30		
	422 65 ×		
	423 43 RCL		
	424 31 31		
	425 75 -		
	426 43 RCL		
	427 55 55		
	428 65 ×		
	429 43 RCL		
	430 31 31		
	431 33 X^2		
	432 75 -		
	433 43 RCL		
	434 57 57		
	435 65 ×		
	436 43 RCL		
	437 32 32		
	438 33 X^2		
	439 75 -		
	440 43 RCL		
	441 58 58		
	442 65 ×		
	443 43 RCL		
	444 30 30		
	445 75 -		
	446 43 RCL		
	447 59 59		
	448 65 ×		
	449 43 RCL		
	450 31 31		
	451 95 =		
	452 55 ÷		
	453 43 RCL		
	454 39 39		
	455 85 +		
	456 43 RCL		
	457 40 40		
	458 33 X^2		
	459 95 =		
	460 34 $\sqrt{x}$		
	461 42 STO		
	462 39 39		
	463 75 -		
	464 43 RCL		
	465 40 40		
	466 95 =		
	467 42 STO		
	468 40 40		
	469 75 -		
	470 02 2		
	471 65 ×		
	472 43 RCL		
	473 39 39		
	474 95 =		
	475 94 +/-		
	476 92 RTN		
	477 00 0		
	478 00 0		
	479 00 0		

	0. 00	0. 00	0. 00	0. 00 00
M_k	1. 00	1. 00	1. 00	1. 00 01
	0. 00	0. 00	0. 00	0. 00 02
	0. 00	0. 00	0. 00	0. 00 03
	8.2872928-03	9.4711918-03	9.3683286-03	13.87939-03 04
	-2.320442-03	-2.6519337-03	-853.99478-06	-586.78489-06 05
	0. 00	0. 00	0. 00	0. 00 06
	8.2872928-06	9.4711918-06	9.3683286-06	13.87939-06 07
	-2.320442-06	-2.6519337-06	-853.99478-09	-586.78489-09 08
	0. 00	0. 00	0. 00	0. 00 09
	0. 00	0. 00	0. 00	0. 00 10
	0. 00	0. 00	0. 00	0. 00 11
	0. 00	0. 00	0. 00	0. 00 12
	0. 00	0. 00	90. 00	90. 00 13
	1. -03	1. -03	500. -06	750. -06 14
	40. 06	40. 06	0. 00	0. 00 15
	3.8447501 00	30.750001 03	1. -03	1. -03 16
	68. 06	68. 06	68. 06	68. 06 17
	2.8358135 03	22.65575 06	22.625 06	22.625 06 18
	10.3 09	10.3 09	10.3 09	10.3 09 19
	5.6677823 03	22.65575 06	22.625 06	22.625 06 20
	0. 00	500. -06	0. 00	500. -06 21
	1. 00	875. -03	750. -03	281.25-03 22
	1. 00	875. -03	1. 00	875. -03 23
	0. 00	0. 00	0. 00	0. 00 24
	0. 00	0. 00	0. 00	0. 00 25
	0. 00	0. 00	0. 00	0. 00 26
	8.2872928-06	9.4711918-06	9.3683286-06	13.87939-06 27
	-2.320442-06	-2.6519337-06	-853.99478-09	-586.78489-09 28
	0. 00	0. 00	0. 00	0. 00 29
	0. 00	0. 00	0. 00	0. 00 30
	0. 00	0. 00	0. 00	0. 00 31
	0. 00	0. 00	0. 00	0. 00 32
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	145.63107-03	166.43551-03	47.278412-03	25.042923-03 34
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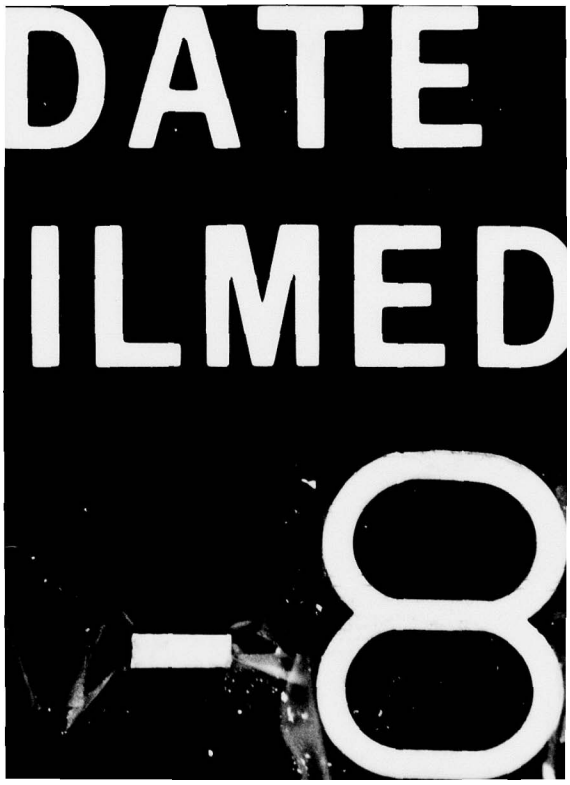
	209.20502-03	239.09145-03	209.20502-03	239.09145-03 36
	0. 00	0. 00	0. 00	0. 00 37
	0. 00	0. 00	0. 00	0. 00 38
	1. 03	875. 00	964.5143 00	667.40582 00 39
	1. 03	875. 00	791.97978 00	516.39171 00 40
S^M	125. -06	125. -06	125. -06	125. -06 41
	1. 03	875. 00	835.69432 00	374.19028 00 42
	26.880431 09	26.880431 09	791.97978 00	516.39171 00 43
	85.73249 09	85.73249 09	85.73249 09	85.73249 09 44
	19.710431 09	19.710431 09	19.710431 09	19.710431 09 45
	1. 00	875. -03	1. 00	875. -03 46
S^{-M}	1. 03	875. 00	4.8092482 03	2.2499333 03 47
	101.62602-18	101.62602-18	1.1370488 03	818.41992 00 48
	0. 00	0. 00	0. 00	0. 00 49
	0. 00	0. 00	0. 00	0. 00 50
	666.66667-12	666.66667-12	666.66667-12	666.66667-12 51
	0. 00	0. 00	0. 00	0. 00 52
	0. 00	0. 00	0. 00	0. 00 53
	12.004384 03	12.004384 03	12.004384 03	12.004384 03 54
	10.680652 03	10.680652 03	10.680652 03	10.680652 03 55
	-3.0691032 03	-3.0691032 03	-3.0691032 03	-3.0691032 03 56
	11.117842 03	11.117842 03	11.117842 03	11.117842 03 57
	60.646995 00	60.646995 00	60.646995 00	60.646995 00 58
	216.59641 00	216.59641 00	216.59641 00	216.59641 00 59

*U.S.Government Printing Office: 1979 — 657-002/583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