

LAMINATE STACKING SEQUENCES FOR SPECIAL ORTHOTROPY

(Application to fibre reinforced composites)

1. NOTATION

A	in-plane stiffness matrix for laminate	N/m	lbf/in
b_ψ	matrix relating stress and strain in (x, y) co-ordinates for each layer at angle ψ	N/m ²	lbf/in ²
B	coupled in-plane and flexural stiffness matrix for laminate	N	lbf
D	flexural stiffness matrix for laminate	N m	lbf in
D_ψ	contribution to flexural stiffness matrix from layers at angle $\pm\psi$	N m	lbf in
k	identification number for a pair of layers, numbered from centre outwards (zero for a central layer)		
K	$\begin{bmatrix} \partial^2 w / \partial x^2 \\ \partial^2 w / \partial y^2 \\ 2\partial^2 w / \partial x \partial y \end{bmatrix}$ column matrix of curvature components of laminate		
M	$\begin{bmatrix} M_x \\ M_y \\ M_{xy} \end{bmatrix}$ column matrix of bending moment intensities in xz - and yz -planes and twisting moment intensity acting about x - and y -axes respectively	N m/m	lbf in/in
n	number of layers in laminate		
n_ψ	number of layers at angle $\pm\psi$ in laminate		
N	$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \end{bmatrix}$ column matrix of direct load intensities and shear load intensity referred to (x, y) co-ordinates	N/m	lbf/in
t	thickness of a layer (thickness of laminate = nt)	m	in
w	deflection of laminate in z -direction	m	in
x, y, z	laminate principal axes		

Issued October 1982

α, β	principal axes of orthotropy of a layer
ϵ	column matrix of mid-plate direct strains and shear strain referred to (x, y) co-ordinates
	$\begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \epsilon_{xy} \end{bmatrix}$
ζ	sum of all ζ_ψ and ζ_* for laminate, equal to n^3
ζ_ψ, ζ_*	defined, respectively, by
	$D_\psi = \frac{t^3}{12} \zeta_\psi \mathbf{b}_\psi \text{ and } D_* = \frac{t^3}{12} \zeta_* \mathbf{b}_*$
ψ	angle of principal axis of orthotropy, α , of layer measured from laminate principal axis, x
	degree degree

1.1 Suffixes

k refers to k th pair of layers

ψ refers to layers at angle ψ

In the special cases where $\psi = 0^\circ$ or 90° or can be either value then ψ is replaced by the appropriate one of the following suffixes

0 refers to layers with $\psi = 0^\circ$

90 refers to layers with $\psi = 90^\circ$

* refers to layers with $\psi = 0^\circ$ or 90°

1.2 Stacking Sequences

+

layer is aligned at + angle ψ to x -axis

–

layer is aligned at – angle ψ to x -axis

*

layer is aligned with either x - or y -axis

Both SI and British units are quoted but any coherent system of units may be used.

2. INTRODUCTION

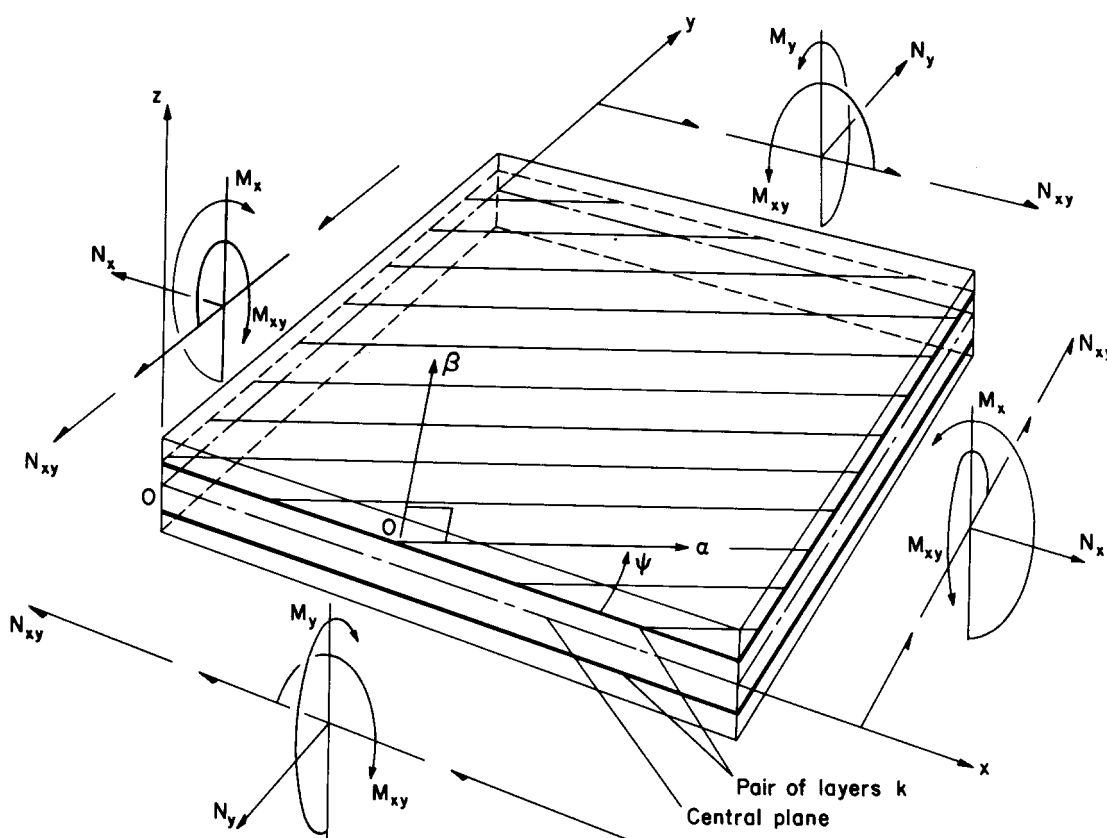
In most structural laminates analysis is simplified, stability is maximised, and distortion during manufacture

is minimised if stacking sequences are used that ensure that end load and shear, and bending and twisting moments, are all uncoupled. The uncoupled condition is termed special orthotropy. This Data Item provides the definitive list of specially orthotropic stacking sequences for laminates of up to 21 layers. In addition notes are given on combining and extending the stacking sequences provided, and on stacking arrangements for laminates with large numbers of layers.

3. DEFINITION OF SPECIAL ORTHOTROPY

The in-plane and flexural stiffness matrices for a structural element to which engineer's theory of bending and twisting can be applied are, using the sign convention of Sketch 3.1, defined as follows.

$$\begin{bmatrix} -\frac{N}{M} \\ -\frac{M}{N} \end{bmatrix} = \begin{bmatrix} \frac{A}{B} & \frac{1}{D} \\ \frac{B}{A} & \frac{1}{D} \end{bmatrix} \begin{bmatrix} -\frac{\varepsilon}{K} \\ -\frac{K}{\varepsilon} \end{bmatrix} \quad (3.1)$$



Sketch 3.1

Specially orthotropic laminates have principal axes of orthotropy. When stiffnesses are referred to these axes they satisfy the following three conditions.

- (1) The in-plane stiffness sub-matrix **A** is orthotropic with direct and shear stiffnesses uncoupled so that A_{13} and A_{23} are zero.
- (2) The flexural stiffness sub-matrix **D** is orthotropic with the bending and twisting stiffnesses uncoupled so that D_{13} and D_{23} are zero.

- (3) The in-plane and flexural stiffness sub-matrices are uncoupled, that is $\mathbf{B} = 0$.

Thus, Equation (3.1) for a specially orthotropic laminate is

$$\begin{bmatrix} N_x \\ N_y \\ N_{xy} \\ M_x \\ M_y \\ M_{xy} \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} & 0 & | & 0 & 0 & 0 \\ & A_{22} & 0 & | & 0 & 0 & 0 \\ & & A_{33} & | & 0 & 0 & 0 \\ - & - & - & + & - & - & - \\ & & & | & D_{11} & D_{12} & 0 \\ & & & | & & D_{22} & 0 \\ & & & | & & & D_{33} \\ \text{symmetric} & & & & & & \end{bmatrix} \begin{bmatrix} \epsilon_x \\ \epsilon_y \\ \epsilon_{xy} \\ \partial^2 w / \partial x^2 \\ \partial^2 w / \partial y^2 \\ 2 \partial^2 w / \partial x \partial y \end{bmatrix} \quad (3.2)$$

4. SEQUENCE TABLES

The Tables 9.1 to 9.4 provide the sequence of layer angles to achieve specially orthotropic laminates of up to 21 layers. The tables include even and odd numbers of layers for both symmetric and anti-symmetric arrangements about the central plane. In each table sequences are listed in ascending value of n with a secondary ordering in ascending values of ζ_ψ . Reference numbers are provided to assist with identification. In the tables the symbol + means that the corresponding layer in the laminate is aligned at an angle $+\psi$ to the x -axis. Similarly a $-$ indicates an alignment of $-\psi$. The symbol * is used for layers with ψ either 0° or 90° , that is, aligned with either the x - or the y -axis. The tables are based upon the following assumptions.

- (1) All layers are orthotropic.
- (2) All layers are of the same thickness.
- (3) The layer principal axes are aligned either with the x - or y -axis or at plus or minus a common angle ψ to the x -axis.
- (4) All layers at angle $+\psi$ or $-\psi$ have the same material properties.
- (5) The two layers of a * pair have the same alignment and material properties.
- (6) In laminates with an odd number of layers the material of the centre layer need not match any other layer.

It follows that the * layers always occur in pairs placed symmetrically about the laminate central plane and that laminates with odd numbers of layers always have a * central layer. Some exceptions to the limitations are described in Section 6.

5. LAMINATE PROPERTIES

In addition to the stacking sequences Tables 9.1 to 9.4 provide the values of n^* , n_ψ , ζ^* , and ζ_ψ that can be used to evaluate $\mathbf{A}$ and $\mathbf{D}$. For the simplest case with only layers aligned with the x -axis or at angle $+\psi$

or $-\psi$ to it, and with all layers using the same material then b_* , n_* and ζ_* become b_0 , n_0 and ζ_0 so that

$$A = t[n_0 \mathbf{b}_0 + n_\psi \mathbf{b}_\psi] \quad (5.1)$$

and
$$D = \frac{t^3}{12}[\zeta_0 \mathbf{b}_0 + \zeta_\psi \mathbf{b}_\psi]. \quad (5.2)$$

Section 4 of Data Item No. 94003* shows how to calculate the matrix $\mathbf{b}$ relating stresses and strains in a layer.

To calculate $\mathbf{A}$ and $\mathbf{D}$ for laminates in which layers are aligned with both the x - and y -axis, that is $\psi = 0^\circ$ and $\psi = 90^\circ$, Equations (5.1) and (5.2) can be extended so,

$$A = t[n_0 \mathbf{b}_0 + n_\psi \mathbf{b}_\psi + n_{90} \mathbf{b}_{90}] \quad (5.3)$$

and
$$D = \frac{t^3}{12}[\zeta_0 \mathbf{b}_0 + \zeta_\psi \mathbf{b}_\psi + \zeta_{90} \mathbf{b}_{90}]. \quad (5.4)$$

Values of ζ_0 and ζ_{90} may be obtained directly from Table 9.5 which lists them as ζ_k together with their summation ζ for laminates with up to 21 layers. Equations are provided at the foot of Table 9.5 for ζ_k should extension beyond 21 layers be required. For each pair of layers with $\psi = 0^\circ$ sum the appropriate ζ_k value to give ζ_0 and for each pair of layers with $\psi = 90^\circ$ sum the appropriate ζ_k to give ζ_{90} . The value ζ_ψ is obtained from Tables 9.1 to 9.4. Note that

$$\zeta_0 + \zeta_\psi + \zeta_{90} = \zeta = n^3. \quad (5.5)$$

Extensions to Equations (5.1) and (5.2) similar to those of Equations (5.3) and (5.4) can be made to account for the different $\mathbf{b}$ matrices if more than one material is used. A more general method of calculating $\mathbf{A}$ and $\mathbf{D}$ is given in Data Item No. 94003 and could be required in some situations described in Section 6.

6. ENLARGEMENT AND COMBINATION OF THE TABULATED SEQUENCES

6.1 Addition of Outer Layers

All the sequences may be enlarged by symmetrically adding a pair of orthotropic layers to the outsides. The pair must be aligned with either the x - or the y -axis. Provided that these criteria of symmetry and alignment are met the additional layers can be of different material and thicknesses from the inner layers. Values of ζ_k appropriate to the added layers can be read directly from Table 9.5 for use in Equations (5.1) and (5.2), or extensions thereof. Example 2 (Section 8.2) illustrates such a case. Further pairs can then be added in a similar way. Also, identical pairs of complete laminates from the tables could be used.

6.2 Asymmetric Sequences

Tables 9.6 and 9.7 list those pairs of symmetric and anti-symmetric sequences that can be combined to give asymmetric sequences which are also specially orthotropic. This is possible where the angled layers in one sequence coincide with the $*$ layers of another sequence (and vice versa) when counting outwards from the laminate centres. The two sequences are interlocked so that the angled layers from one replace the $*$ layers of the other. For the new sequence ζ is the sum of the ζ_ψ values from the two sequences used and ζ_* is given by $\zeta - \zeta_\psi (= n^3 - \zeta_\psi)$.

* Data Item No. 94003 "Stiffnesses of laminated flat plates".

An example of this is sequence S 2 which, when interlocked with sequence A 171, yields the following 20 layer sequence.

$$+ * - + - - - + * + \quad + * - - + - + + * -.$$

In this case $\zeta_{\psi} = 2048 + 4160 = 6208$

and $\zeta_* = \zeta - \zeta_{\psi} = n^3 - \zeta_{\psi} = 20^3 - 6208 = 1792.$

6.3 Laminates with Two Layer Angles

Sequences with the same form of symmetry can be interlocked in the same way as described in Section 6.2. This would repeat another sequence already in the tables but can be used to introduce two different values of ψ .

If sequence A 1 using $\psi = 45^\circ$ is combined with sequence A 48 using $\psi = 30^\circ$ the resulting sequence is

$$+ 30, - 30, - 30, + 30, + 45, - 45, - 45, + 45 \quad - 45, + 45, + 45, - 45, - 30, + 30, + 30, - 30.$$

In this case ζ_{30} is 3584 (from A 48) and ζ_{45} is 512 (from A 1). These must be used with the correct $\mathbf{b}_{\psi}$ matrices. It is evident that ζ_* is zero as this sequence contains no * layers. This result could have been calculated from Equation (5.5) since

$$3584 + 512 = 4096 = 16^3.$$

6.4 Sequences of Particular Interest

There are two types of sequence that may be expanded by the insertion of additional orthotropic layers. The first is of the form

$$+ - \text{stars} - * + \text{stars} + -$$

as in A 381, A 382, A 385, A 390, A 402, A 432 and A 502 of Table 9.4.

The second is of the form

$$+ - - + \text{stars} - + + -$$

as in A 1, A 4, A 9, A 21, A 48, A 117, A 283, A 383, A 387, A 396, A 416, A 466, and A589 in Tables 9.3 and 9.4. The stars may represent pairs of 0° or 90° layers, or other orthotropic material as in a sandwich panel. Note that if this affects assumptions (2) or (6) of Section 4 the values of ζ given in the tables are not valid. In such cases the method given in Data Item No. 94003 is recommended for calculation of stiffnesses.

6.5 Design of Laminates with Many Layers

Laminates with more than 21 layers are generally designed with equal numbers of plus and minus angle layers and symmetric sequences. This process usually results in stiffnesses that approximate to the conditions of special orthotropy. Re-arrangement to meet these conditions more closely is usually only

necessary if a large deviation becomes apparent on calculation of the stiffnesses in Equation (3.2).

7. DERIVATION

This Section gives the selected source that has assisted in the preparation of this Data Item.

1. BARTHOLOMEW, P. Ply stacking sequences for laminated plates having in-plane and bending orthotropy. Royal Aircraft Establishment Technical Report No. 76003, February 1976.

8. EXAMPLES

8.1 Example 1

A laminated plate is required for a shear panel. Thirteen layers are to be used of which 50 to 75 per cent are required to have ψ at 45° to the plate axes and the rest are required to be parallel to the plate x -axis.

Tables 9.2 and 9.4 deal with odd numbers of layers. Since $n = 13$ and Table 9.2 has $n \geq 15$, Table 9.4 lists all the possible sequences. These are A 388, A 391, A 392, A 394, and A 396. Also A 383, A 386, and A 387 could be used with 0° layers added externally. A choice between these might be made based on flexural stiffnesses which can be calculated using Equation (5.2) or by the methods of Data Item No. 94003 or otherwise. To obtain the maximum torsional stiffness, if that was required, A 396 would be selected giving the sequence:

$$+ 45^\circ, -45^\circ, -45^\circ, +45^\circ, 0^\circ, 0^\circ, 0^\circ, 0^\circ, -45^\circ, +45^\circ, +45^\circ, -45^\circ.$$

8.2 Example 2

A laminate is required to have a torsional stiffness, D_{33} , of at least 7 N m. In order to carry direct loads it is necessary to have 10 layers of carbon fibre composite with thickness $t = 0.125$ mm. Within these constraints it is required to maximise the bending stiffness D_{11} . The matrix relating stress and strain in (x, y) co-ordinates for a layer aligned with the x -axis is

$$\mathbf{b} = \begin{bmatrix} 208 & 2.29 & 0 \\ 2.29 & 7.63 & 0 \\ 0 & 0 & 5 \end{bmatrix} \times 10^9 \text{ N/m}^2.$$

Tables 9.1 and 9.3 deal with even numbers of layers. Table 9.1 does not list any sequences with $n = 10$. In Table 9.3 there are 3 sequences that have the required number of layers. These are A 2, A 3, and A 4; also sequence A 1 (8 layers) is suitable if a pair of layers is added externally as described in Section 6.1. The added pair will be the fifth pair so that, from Table 9.5, $\zeta_5 = 488$. Because the value of ζ_* for sequence A 1, listed in Table 9.3, is zero the value of ζ_* for the enlarged sequence becomes 488. The value of ζ_ψ is unchanged at 512. (Note that $\zeta_* + \zeta_\psi = 1000 = n^3$.)

The four sequences are now considered with, initially, the angled layers at $\psi = 45^\circ$ because this maximises D_{33} . For this angle the required terms of the $\mathbf{b}_\psi$ matrix, calculated using Data Item No. 94003, are $b_{11} = 60 \times 10^9 \text{ N/m}^2$ and $b_{33} = 52.7 \times 10^9 \text{ N/m}^2$. Other layers are at 0° . Then Equation (5.2) and values from Table 9.3 are used to calculate the flexural stiffnesses.

Sequence A 1: 0 + - - + - + + - 0.

Using Equation (5.2),

$$D_{11} = \frac{(0.125 \times 10^{-3})^3}{12} [488 \times 208 + 512 \times 60] \times 10^9 = 21.5 \text{ N m}$$

and

$$D_{33} = \frac{(0.125 \times 10^{-3})^3}{12} [488 \times 5 + 512 \times 52.7] \times 10^9 = 4.79 \text{ N m}.$$

The effect of the 0° layers on the outside is to give a large D_{11} , but D_{33} is inadequate for requirements.

Sequence A 2: + 0 - - - + + + 0 -.

$$D_{11} = \frac{(0.125 \times 10^{-3})^3}{12} [296 \times 208 + 704 \times 60] \times 10^9 = 16.9 \text{ N m}$$

and

$$D_{33} = \frac{(0.125 \times 10^{-3})^3}{12} [296 \times 5 + 704 \times 52.7] \times 10^9 = 6.28 \text{ N m}.$$

Moving the 0° layers inwards lowers D_{11} and increases D_{33} but not to the value required.

Sequence A 3: + - 0 - + - + 0 + -.

$$D_{11} = \frac{(0.125 \times 10^{-3})^3}{12} [152 \times 208 + 848 \times 60] \times 10^9 = 13.4 \text{ N m}$$

and

$$D_{33} = \frac{(0.125 \times 10^{-3})^3}{12} [152 \times 5 + 848 \times 52.7] \times 10^9 = 7.40 \text{ N m}.$$

This sequence meets the requirements for D_{33} .

Sequence A 4: + - - + 0 0 - + + -.

$$D_{11} = \frac{(0.125 \times 10^{-3})^3}{12} [8 \times 208 + 992 \times 60] \times 10^9 = 9.96 \text{ N m}$$

and

$$D_{33} = \frac{(0.125 \times 10^{-3})^3}{12} [8 \times 5 + 992 \times 52.7] \times 10^9 = 8.52 \text{ N m}.$$

A high value of D_{33} is obtained from grouping the angle layers on the outside, but D_{11} is reduced.

Sequences A 1 and A 2 are rejected by the above calculations since in both D_{33} is too low. With ψ fixed at 45° sequence A 4 gives the highest D_{33} . However, both A 3 and A 4 may be improved by reducing ψ . Assuming 5° increments are allowable, sequence A 4 can use 35° layers and A 3 40° layers to provide a laminate the torsional stiffness of which does not fall below the required value.

For sequence A 3 with $\psi = 40^\circ$, $D_{11} = 16.0 \text{ N m}$ and $D_{33} = 7.2 \text{ N m}$.

For sequence A 4 with $\psi = 35^\circ$, $D_{11} = 16.4 \text{ N m}$ and $D_{33} = 7.6 \text{ N m}$.

Thus, sequence A 4 is selected to satisfy the requirement and is

$$+ 35^\circ, - 35^\circ, - 35^\circ, + 35^\circ, 0^\circ \quad 0^\circ, - 35^\circ, + 35^\circ, + 35^\circ, - 35^\circ.$$

The stiffnesses of the laminate are given below.

$$\mathbf{A} = \begin{bmatrix} 152 & 45.0 & 0 \\ 45.0 & 33.2 & 0 \\ 0 & 0 & 48.4 \end{bmatrix} \times 10^6 \text{ N/m}$$

and

$$\mathbf{D} = \begin{bmatrix} 16.4 & 7.17 & 0 \\ 7.17 & 5.07 & 0 \\ 0 & 0 & 7.61 \end{bmatrix} \text{ N m}.$$

9. TABLES OF LAMINATE PROPERTIES

TABLE 9.1 Symmetric Laminates with Even Numbers of Layers

Reference number	Sequence	n	n_ψ	n_0	ξ_ψ	ξ_0	n_ψ/n	$\xi_\psi/\xi = \xi_\psi/n^3$
S 1	+--*+* *+*--+	12	8	4	1568	160	0.667	0.907
S 2	+-*+**+ +**-*--+	14	8	6	2048	696	0.571	0.746
S 3	+--*+*+ -++*--+	14	12	2	2448	296	0.857	0.892
S 4	+--+*+* *+*--+	14	12	2	2736	8	0.857	0.997
S 5	+-*+*** **+*--+	16	8	8	3008	1088	0.500	0.734
S 6	+*--+*+ +*+--+	16	12	4	3024	1072	0.750	0.738
S 7	+-*+*+ +*+--+	16	12	4	3312	784	0.750	0.809
S 8	+--*+*+* *--+*--+	16	12	4	3600	496	0.750	0.879
S 9	+--+*+* *+*--+	16	12	4	3792	304	0.750	0.926
S 10	+--+*+*+ -++*--+	16	16	0	4096	0	1.000	1.000
S 11	+*--****+ +****-+*	18	8	10	3488	2344	0.444	0.598
S 12	+***--+*+ +-***-+*	18	12	6	3600	2232	0.667	0.617
S 13	+*--*+*+ +*--*+*	18	12	6	3600	2232	0.667	0.617
S 14	+***+*+*+ +-***+*+*	18	12	6	3792	2040	0.667	0.650
S 15	+-*+*+*+ -+*+*+*	18	12	6	4176	1656	0.667	0.716
S 16	+-*+*+*+ +*+*+*+*	18	12	6	4464	1368	0.667	0.765
S 17	+*--++*+* -++*+*+*	18	16	2	4480	1352	0.889	0.768
S 18	+-*+*+** **+*+*+*	18	12	6	4752	1080	0.667	0.815
S 19	+--*+*+* -*+*+*+*	18	12	6	4752	1080	0.667	0.815
S 20	+--*+*+** **--+*+*+*	18	12	6	5040	792	0.667	0.864
S 21	+--+*+*+* *+*+*+*	18	12	6	5040	792	0.667	0.864
S 22	+--+*+*+* -++*+*+*	18	16	2	5344	488	0.889	0.916
S 23	+--+*+*+* *--+*+*+*	18	16	2	5824	8	0.889	0.999
S 24	+***+*+*+ *+***+*+*	20	8	12	4448	3552	0.400	0.556
S 25	+*--*+*+* +-***+*+*	20	12	8	4464	3536	0.600	0.558
S 26	+**--*+*+ +*+*--*+*	20	12	8	4464	3536	0.600	0.558

TABLE 9.1 (continued)

Reference number	Sequence	n	n_ψ	n_0	ξ_ψ	ξ_0	n_ψ/n	$\xi_\psi/\xi = \xi_\psi/n^3$
S 27	+*--***+--	20	12	8	4752	3248	0.600	0.594
S 28	+*--*-+*+*	20	12	8	4752	3248	0.600	0.594
S 29	+***+****	20	8	12	4928	3072	0.400	0.616
S 30	+*--***+*+	20	12	8	5040	2960	0.600	0.630
S 31	+*--*+--+	20	16	4	5248	2752	0.800	0.656
S 32	+*--*+***	20	12	8	5328	2672	0.600	0.666
S 33	+*--*+*+*	20	12	8	5616	2384	0.600	0.702
S 34	+*--*+--+	20	16	4	5632	2368	0.800	0.704
S 35	+*--*+***	20	12	8	5808	2192	0.600	0.726
S 36	+*--*+--+	20	16	4	5920	2080	0.800	0.740
S 37	+*--*+***	20	12	8	6096	1904	0.600	0.762
S 38	+*--*+*+*	20	16	4	6208	1792	0.800	0.776
S 39	+*--*+***	20	12	8	6480	1520	0.600	0.810
S 40	+*--*+--+	20	16	4	6496	1504	0.800	0.812
S 41	+*--*+***	20	16	4	6496	1504	0.800	0.812
S 42	+*--*+*+*	20	16	4	6496	1504	0.800	0.812
S 43	+*--*+***	20	12	8	6768	1232	0.600	0.846
S 44	+*--*+*+*	20	16	4	6784	1216	0.800	0.848
S 45	+*--*+*+*	20	16	4	7264	736	0.800	0.908
S 46	+*--*+*+*	20	16	4	7648	352	0.800	0.956
S 47	+*--*+***	20	16	4	7936	64	0.800	0.992
S 48	+*--*+***	20	16	4	7936	64	0.800	0.992

TABLE 9.2 Symmetric Laminates with Odd Numbers of Layers

Reference number	Sequence	n	n_ψ	n_o	ξ_ψ	ξ_o	n_ψ/n	$\xi_\psi/\xi = \xi_\psi/n^3$
S 49	+--*++ * -++--+	15	12	3	2998	387	0.800	0.885
S 50	+--***+ * +**--+	17	8	9	3128	1785	0.471	0.637
S 51	+*---++ * *++--+	17	12	5	3708	1205	0.706	0.755
S 52	+--*++ * *--++	17	12	5	4284	629	0.706	0.872
S 53	+---++ * -++-+	17	16	1	4912	1	0.941	0.999
S 54	+*---**+ * *+***-	19	8	11	4088	2771	0.421	0.596
S 55	+*-+*+ * -+*+*	19	12	7	4680	1999	0.632	0.709
S 56	+--**++ * +*+**+	19	12	7	4716	2143	0.632	0.688
S 57	+---*++ * **++-	19	12	7	5868	991	0.632	0.855
S 58	+---*++ * -++-+	19	16	3	6256	603	0.842	0.912
S 59	+---*++ * *--++	19	16	3	6832	27	0.842	0.996
S 60	+*---**+ * +*+**+	21	12	9	5052	4209	0.571	0.546
S 61	+**---*+ * +*+**+	21	12	9	5292	3969	0.571	0.571
S 62	+--***+ * +*+***+	21	12	9	5292	3969	0.571	0.571
S 63	+*---*+ * +*+**+	21	12	9	5628	3633	0.571	0.608
S 64	+*-+*+ * **++-	21	12	9	6012	3249	0.571	0.649
S 65	+--**++ * +*+**+	21	12	9	6060	3201	0.571	0.654
S 66	+*---*+ * +*+**+	21	12	9	6204	3057	0.571	0.670
S 67	+*-+*+ * *--++	21	12	9	6444	2817	0.571	0.696
S 68	+*---++ * -++-+	21	16	5	7216	2045	0.762	0.779
S 69	+--*++ * -++-+	21	16	5	7216	2045	0.762	0.779
S 70	+*-+*+ * -+*+*	21	16	5	7504	1757	0.762	0.810
S 71	+--*++ * ***++	21	12	9	7740	1521	0.571	0.836
S 72	+---*++ * -++-+	21	16	5	7792	1469	0.762	0.841
S 73	+---*++ * *--++	21	16	5	8368	893	0.762	0.904
S 74	+---***+ * +*+**+	21	16	5	8944	317	0.762	0.966
S 75	+---*++ * **++-	21	16	5	9136	125	0.762	0.987