5.4.4 Specially Orthotropic Lamina

Any lamina is orthotropic in its own lamina coordinate system $(1, 2, 3)$. A lamina is called *specially orthotropic* when it is also orthotropic in the laminate coordinate system (x, y, z), which happens only for orientations $\theta = 0°$ and $\theta = 90°$, or for laminas reinforced with balanced fabrics (see Example 5.7). An orthotropic lamina that is oriented at an angle not a multiple of 90° from the laminate coordinate system is called *generally orthotropic*. Therefore $\bar{Q}_{16}$, $\bar{Q}_{26}$, $\bar{S}_{16}$, and $\bar{S}_{26}$ are different from zero for a generally orthotropic lamina.

Example 5.7 *Compute the $[\bar{Q}]$ matrix of a lamina reinforced with a ±45 woven fabric. The fabric weight is $w = 600$ g/m^2 of which 300 g are at +45° and 300 g are at −45°. The matrix is epoxy HTP-1072 (Tables 2.13–2.14). The fiber is Kevlar 49™ (Tables 2.3–2.4) and the fiber volume fraction is 50%.*

Solution to Example 5.7 *First assume that the +45 and the −45 fibers are separated in two laminas. Compute the $[Q]$ matrix of the unidirectional material. Using (4.23), (4.29), (4.35), and (4.31) results in $E_1 = 67192$ MPa, $E_2 = 12139$ MPa, $G_{12} = 3347$ MPa, and $\nu_{12} = 0.365$. Then, using (5.24) results in*

$$Q = \begin{bmatrix} 68848 & 4540 & 0 \\ 4540 & 12438 & 0 \\ 0 & 0 & 3447 \end{bmatrix} \; MPa$$

Then compute the $[\bar{Q}]$ matrices using (5.54)

$$[\bar{Q}]_{45} = \begin{bmatrix} 26038 & 19144 & 14102 \\ 19144 & 26038 & 14102 \\ 14102 & 14102 & 18052 \end{bmatrix} \; MPa; \quad [\bar{Q}]_{-45} = \begin{bmatrix} 26038 & 19144 & -14102 \\ 19144 & 26038 & -14102 \\ 14102 & 14102 & -18052 \end{bmatrix}$$

Finally, average them to get

$$[\bar{Q}]_{fabric} = \frac{300}{600}[\bar{Q}]_{45} + \frac{300}{600}[\bar{Q}]_{-45} = \begin{bmatrix} 26038 & 19144 & 0 \\ 19144 & 26038 & 0 \\ 0 & 0 & 18052 \end{bmatrix} \; MPa$$

Note that the effect of using a balanced fabric is to cancel $\bar{Q}_{16}$ and $\bar{Q}_{26}$. Therefore, balanced fabrics produce a specially orthotropic lamina.

SCILAB *code for this example is available on the Website [4].*

Example 5.8 *Compute the $[\bar{Q}]$ matrix of one lamina of stitched fabric XM2408 (Table 2.12). The fiber is E-glass (Tables 2.1–2.2), the fiber volume fraction is 50%, and the matrix is epoxy HTP-1072 (Tables 2.13–2.14).*