Evaluation of the elastic stiffnesses of multi-directional laminates by bending tests

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Situations may arise in which the elastic stiffnesses of composite laminates are to be evaluated with a limited quantity of available material. Besides, tensile testing may not be possible due to inadequate geometries of the available samples with respect to the laboratory equipment, etc. In such cases, three- or four-point bending tests may result as a simple and effective alternative to tensile tests [1]. ASTM international specifies how to evaluate the flexural properties of polymer matrix composite materials by bending tests [2]. Shear stiffnesses of unidirectional laminates may also be determined by executing an adequate number of non-destructive three-point bending tests at different span lengths [3].

We extend the above procedure to multidirectional laminates, whose geometry and stacking sequence are known, but not the elastic properties of the plies. First, we measure the values of specimen compliance from experiments at different span lengths. Hence, we determine the homogenised bending and shear stiffnesses of the laminate based on Timoshenko's beam theory [4]. Lastly, we obtain the Young's modulus and shear modulus of the constituting plies by reversing the usual procedure of calculating the laminate stiffnesses from ply properties through the classical theory of laminates [5]. We apply the procedure to carbon/epoxy unidirectional laminated specimens, tested elsewhere to determine their interlaminar fracture toughness [6], and to multidirectional glass fibre-reinforced laminates, used in the strengthening of road bridges [7].

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