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The determination of the mode II adhesive fracture resistance, G_{IIC}, of structural adhesive joints: an effective crack length approach

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Abstract

This paper reports results from the mode II testing of adhesively-bonded carbon-fibre-reinforced composite substrates using the end-loaded split (ELS) method. Two toughened, structural epoxy adhesives were employed (a general purpose grade epoxy-paste adhesive, and an aerospace grade epoxy-film adhesive). Linear Elastic Fracture Mechanics was employed to determine values of the mode II adhesive fracture energy, G_{IIC} for the joints via various forms of corrected beam theory. The concept of an effective crack length is invoked and this is then used to calculate values of G_{IIC}. The corrected beam theory analyses worked consistently for the joints bonded with the epoxy-paste adhesive, but discrepancies were encountered when analysing the results of joints bonded with the epoxy-film adhesive. During these experiments, a microcracked region ahead of the main crack was observed, which led to difficulties in defining the *true* crack length. The effective crack length approach provides an insight into the likely errors encountered when attempting to measure mode II crack growth experimentally.

Keywords: Adhesive joints; Mode II; Fracture mechanics; Corrected beam theory; End-loaded split test; Microcracking; Effective crack length

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Nomenclature

a	measured crack length
a_c	calculated crack length
a_e	effective crack length
b	width of joint
C	compliance ($C = \delta/P$)
C_o	uncracked beam compliance (with $a = 0$)
CBT	corrected beam theory
CBTE	corrected beam theory with effective crack length
δ	displacement
Δ_I	mode I length correction
Δ_{II}	mode II length correction
Δ_{clamp}	clamp correction
E_1	flexural modulus of substrate
ECM	experimental compliance method
ELS	end-loaded split test
F	finite displacement correction factor
G_{IC}	Mode I adhesive fracture energy
G_{IIC}	Mode II adhesive fracture energy
h	height of substrate beam
L	free-length (between the clamp point and the load line) in the ELS test
l_1	height of loading pin above upper substrate neutral axis
l_2	half loading block length
m	slope to the C versus a^3 data
N	correction factor to account for the loading block
P	load
θ	see Appendix A
SBT	simple beam theory

1. Introduction

Previous research has focussed on the development of test methods and data analysis schemes for the determination of mode I adhesive fracture energies in structural adhesive joints. Following a multi-laboratory round-robin exercise [1], this work led to the publication of a new British Standard [2] for the determination of G_{IC}. However, the mode II, or in-plane shear, loading mode has particular importance for adhesive joints and fibre-reinforced composites because cracks will frequently be directionally constrained by the nearby substrates, or layers of fibres in a composite, to grow parallel to this constraint. In addition, adhesive joints are usually designed to minimise any applied mode I loading (to which the joints have least fracture resistance) in favour of designs which promote mode II loading (to which they have greater crack resistance) [3].

Mode II loading may be induced when a cracked adhesive joint or composite is subjected to bending and the various experimental fracture mechanics approaches to mode II usually utilise some form of test specimen which is subjected to applied bending loads with a view to determining values of the critical energy release rate for fracture, G_{IIC}. Some popular mode II adhesive joint test specimens are shown in Fig. 1, some having been adapted from earlier work on fibre-reinforced polymer composites. Such specimens uti-