Determination of the envelopes for mode-mixity evaluation for adhesively bonded steel

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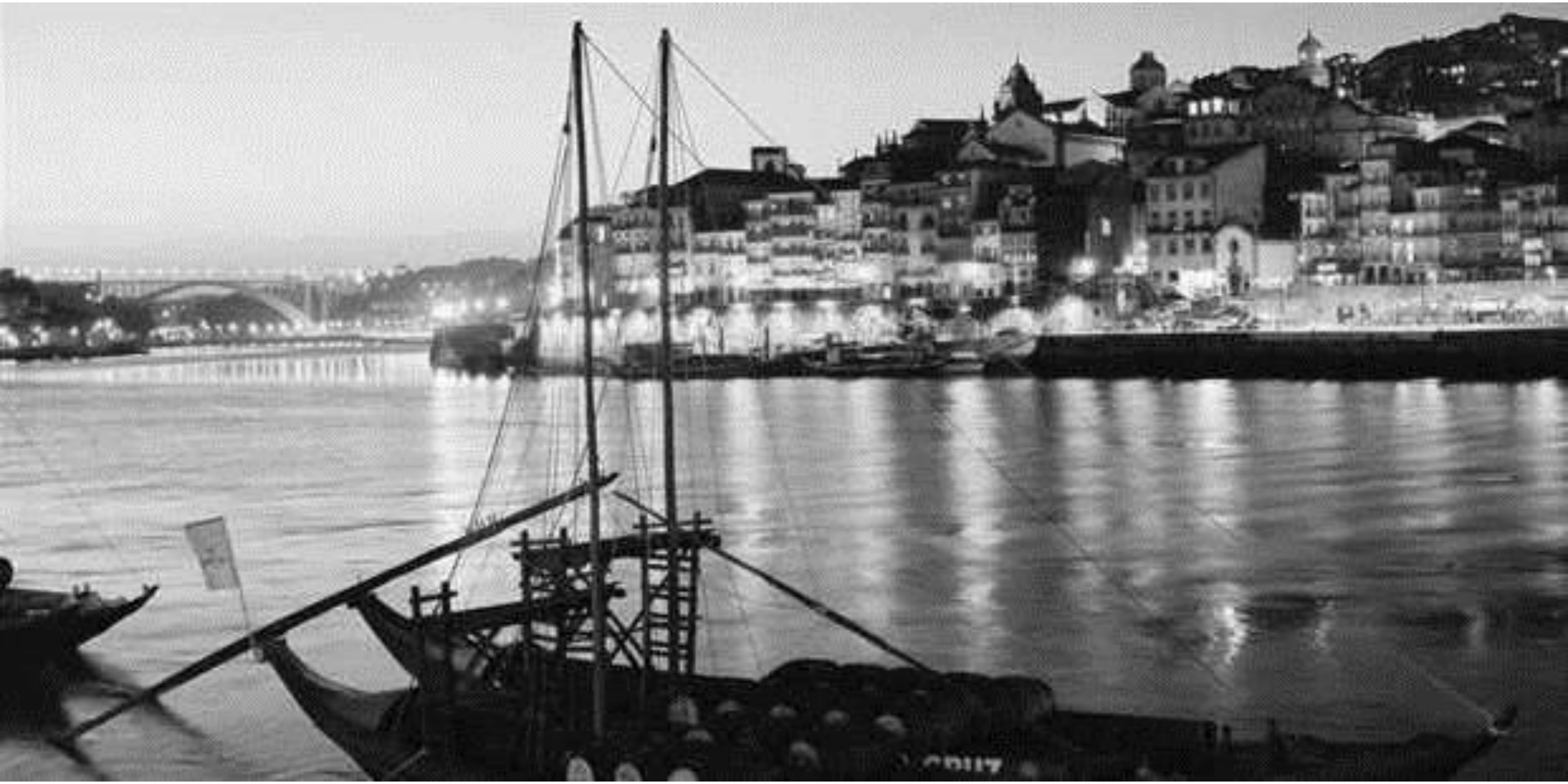


CIFIE 2010- **Iberian Conference on Fracture and Structural Integrity 2010**

[Polymers]

17.03.10

outline

1 motivation

2 mode I tests

3 mode II tests

4 mixed-mode (mode I + mode II) tests

5 double actuator loading frame

6 data reduction

7 results

8 envelope (Arladite® 2015)

9 numerical analysis (improving the data reduction)

10 conclusions

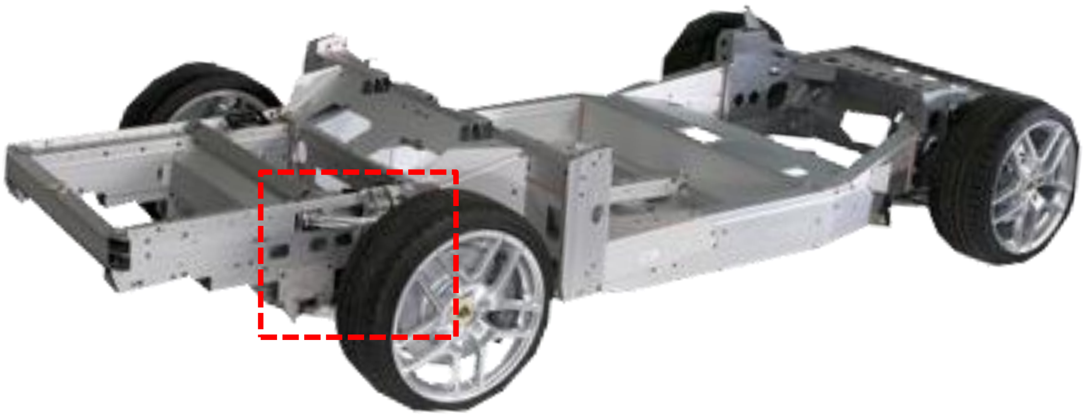
11 next step (future work)

12 acknowledgments

motivation

detail

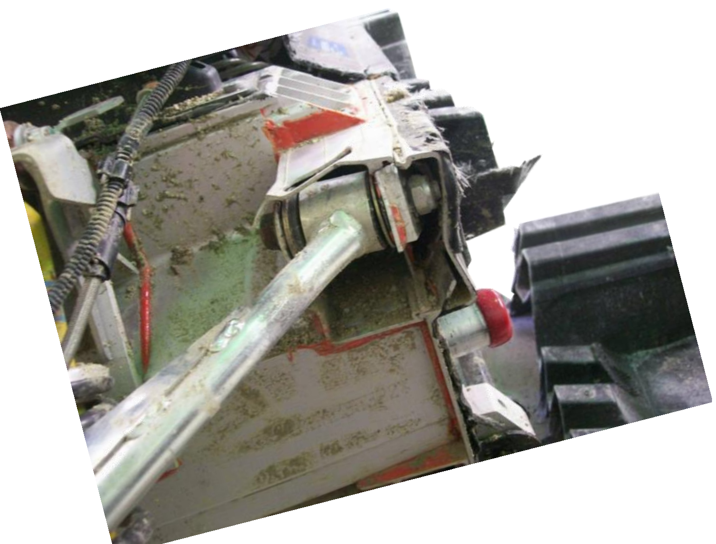
Lotus Elise Chassis

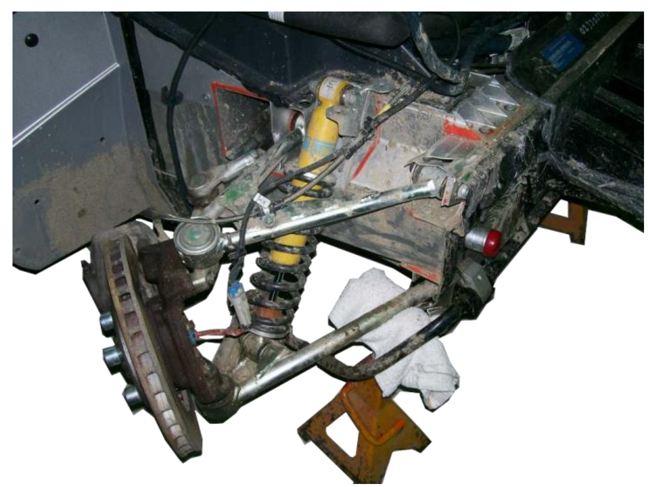


Predict the structure toughness

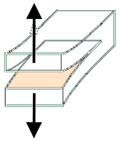
Joint mechanical behavior

Adhesive fracture energies in Mode I, Mode II (and Mode III)

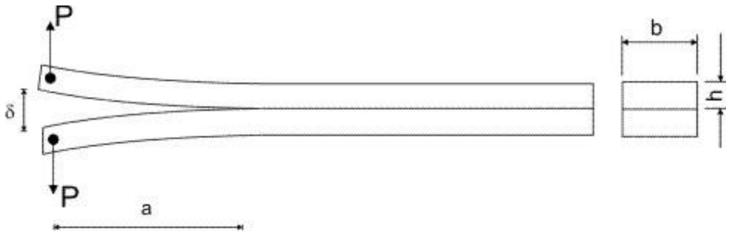




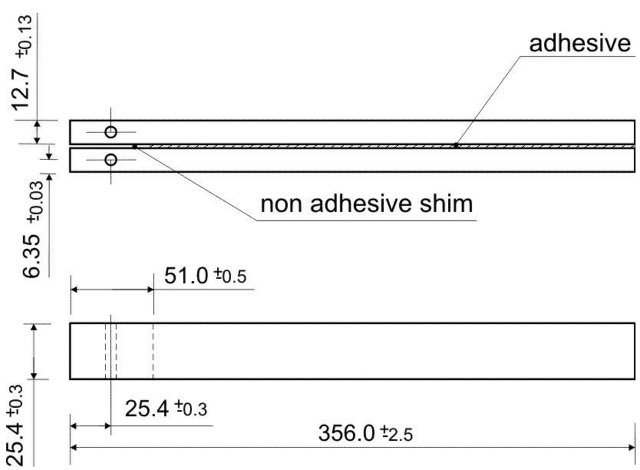
Mode I



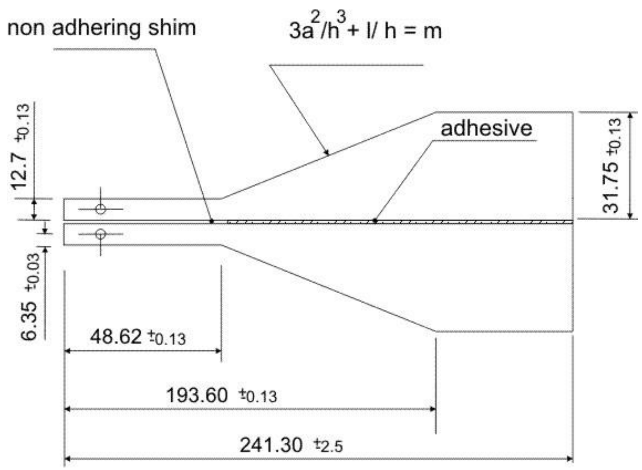
ASTM D 3433 -99



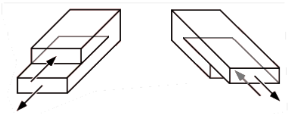
Double Cantilever Beam [DCB]



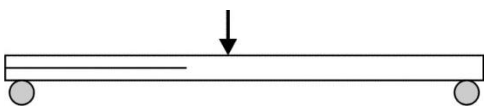
Tapered Double Cantilever Beam [TDCB]



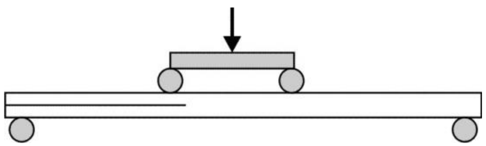
Mode II



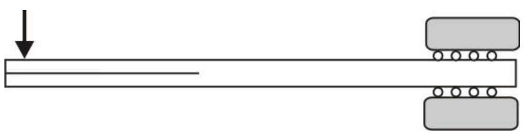
End Notch Flexure [ENF]

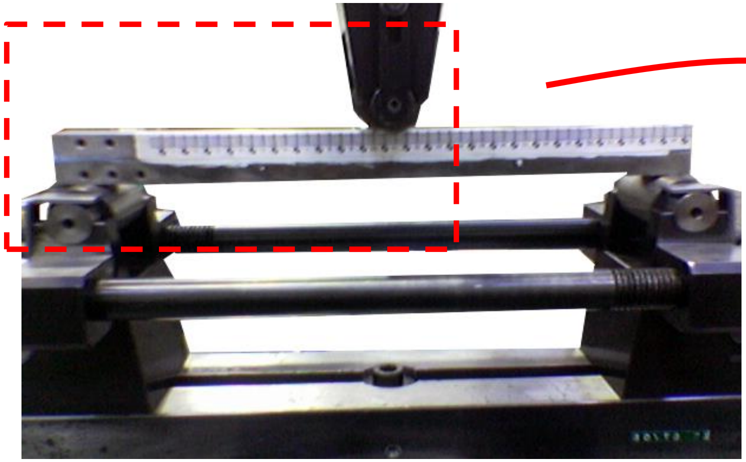


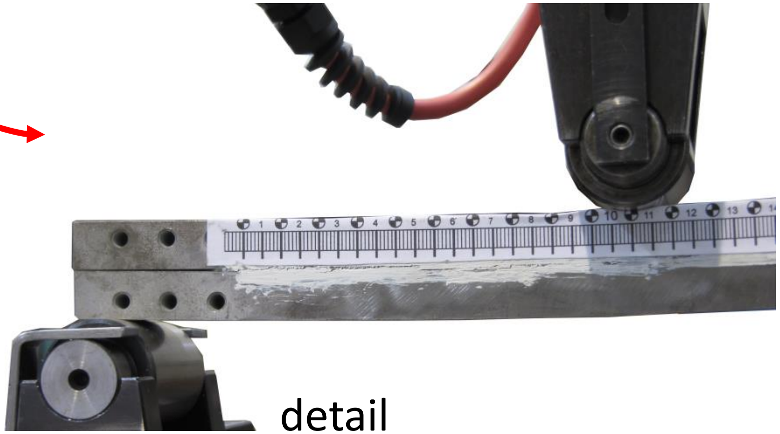
4 Points End Notch Flexure [4 ENF]

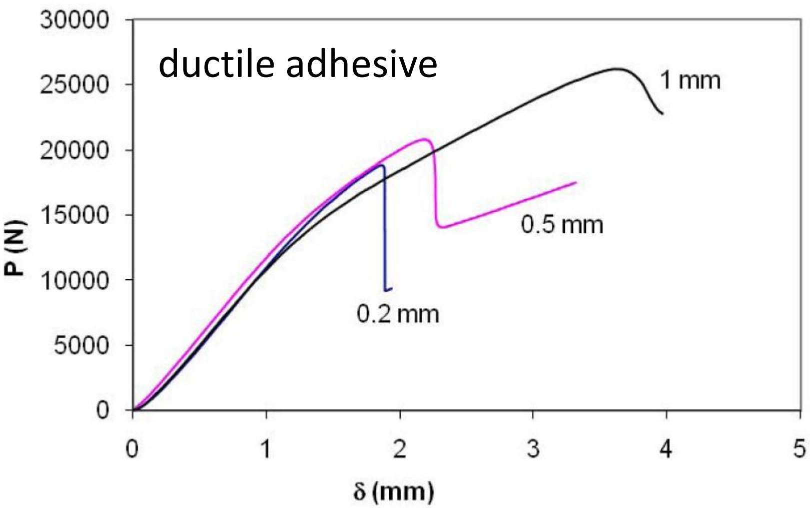


End Loaded Split [ELS]

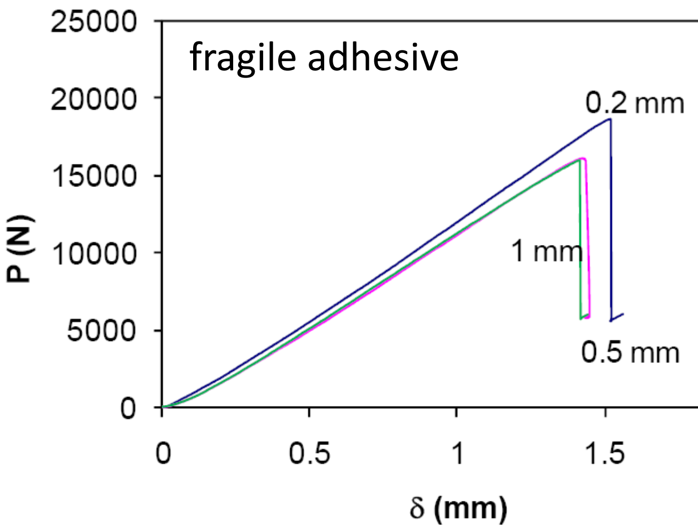




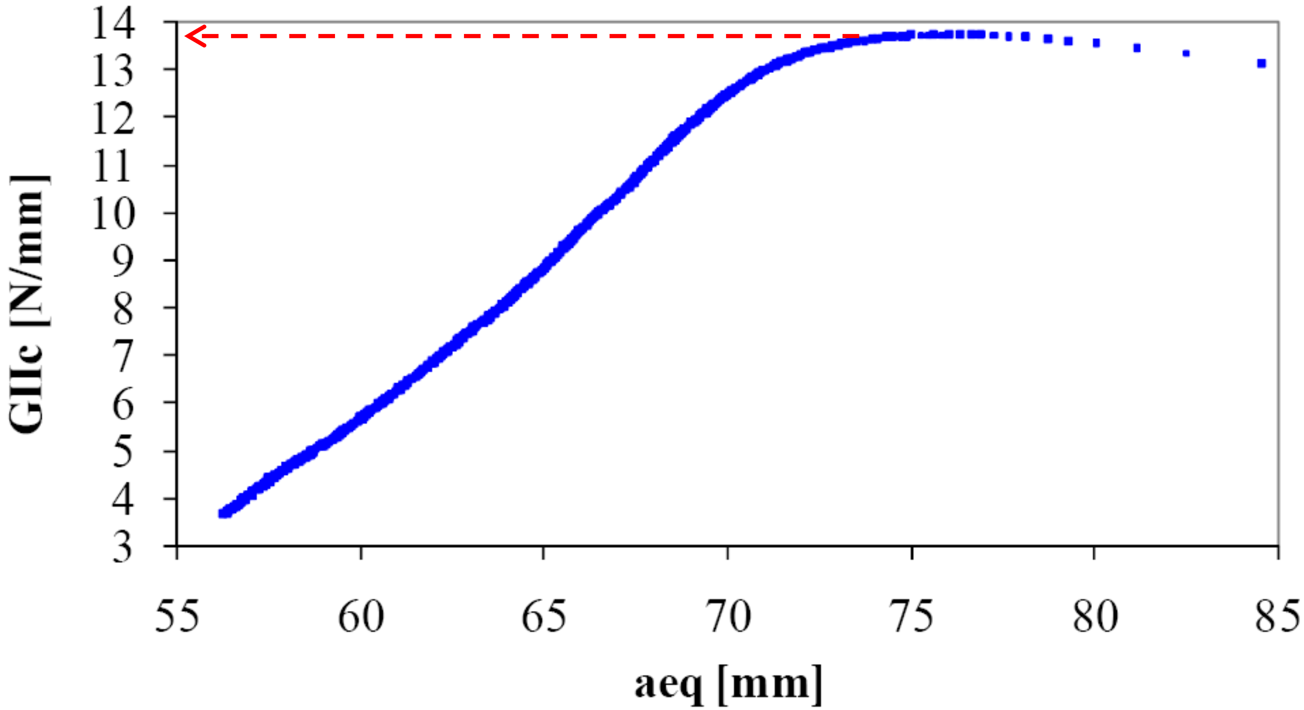




Representative experimental *P–δ curves of the ENF specimens with ARALDITE* 2015 as a function of the adhesive thickness.

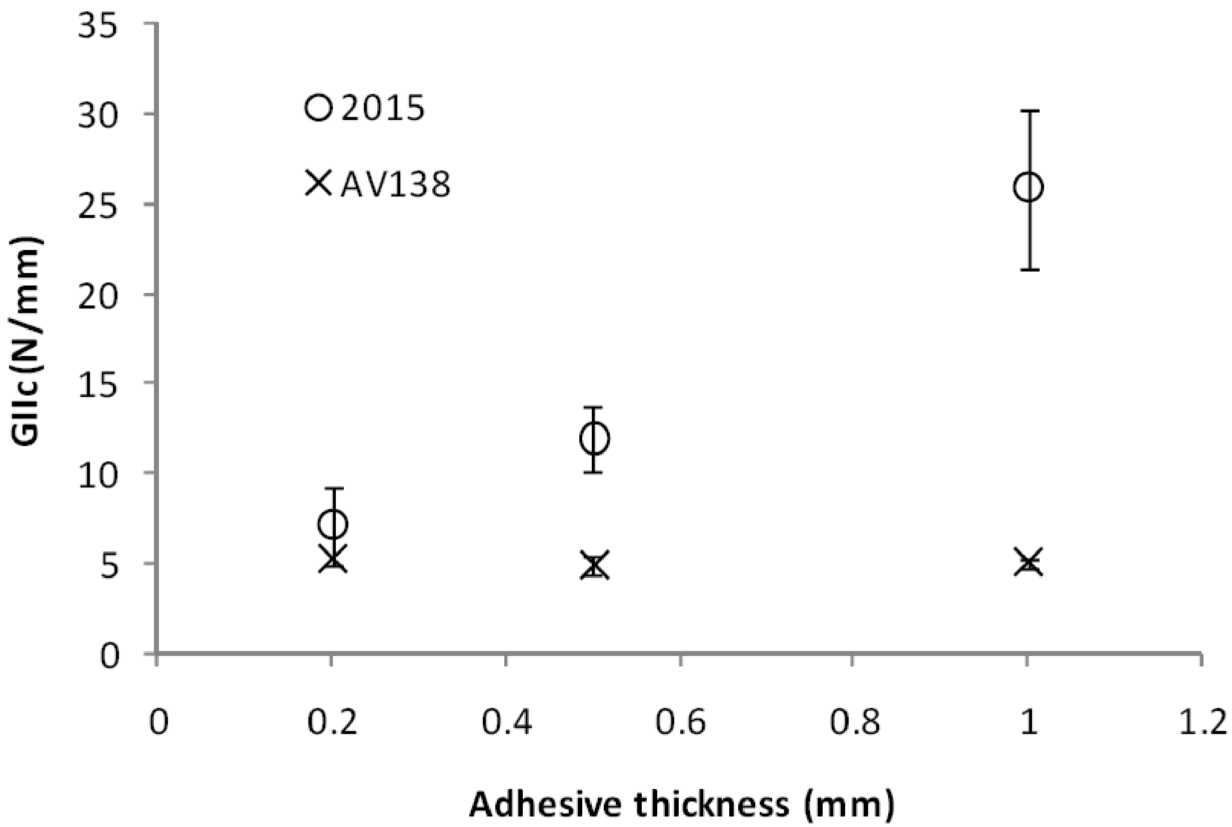


Representative experimental *P–δ curves of the ENF specimens with ARALDITE* AV138M + HV998 as a function of the adhesive thickness.



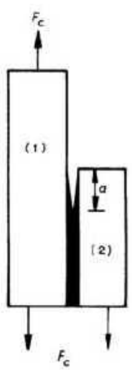
Typical experimental *R-curve obtained for the ARALDITE 2015 for* thickness of 0.5 mm.

Mode II fracture toughness (*GIIc) as a function of the adhesive thickness for a* ductile adhesive (ARALDITE 2015) and a brittle adhesive (ARALDITE AV138M+HV998).

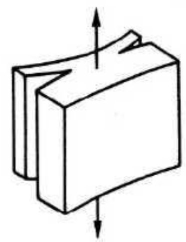


Mixed - Mode (I + II)

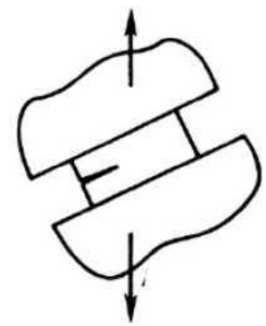
Crack Lap Shear [CLS]



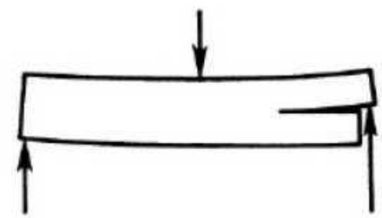
Edge Delamination Tension [EDT]



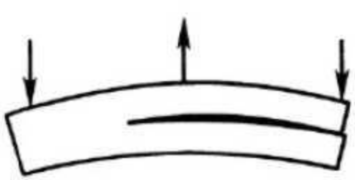
Arcan



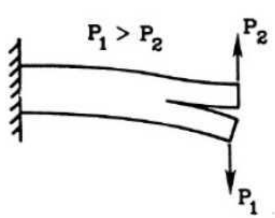
Mixed Mode Flexure [MMF]



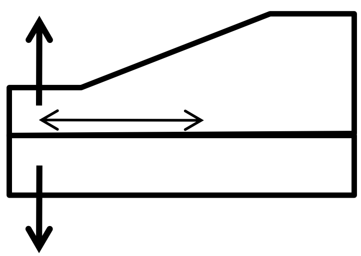
Mixed Mode Bending [MMB]
ASTM D6671



Asymmetrical Double Cantilever Beam [ADCB]

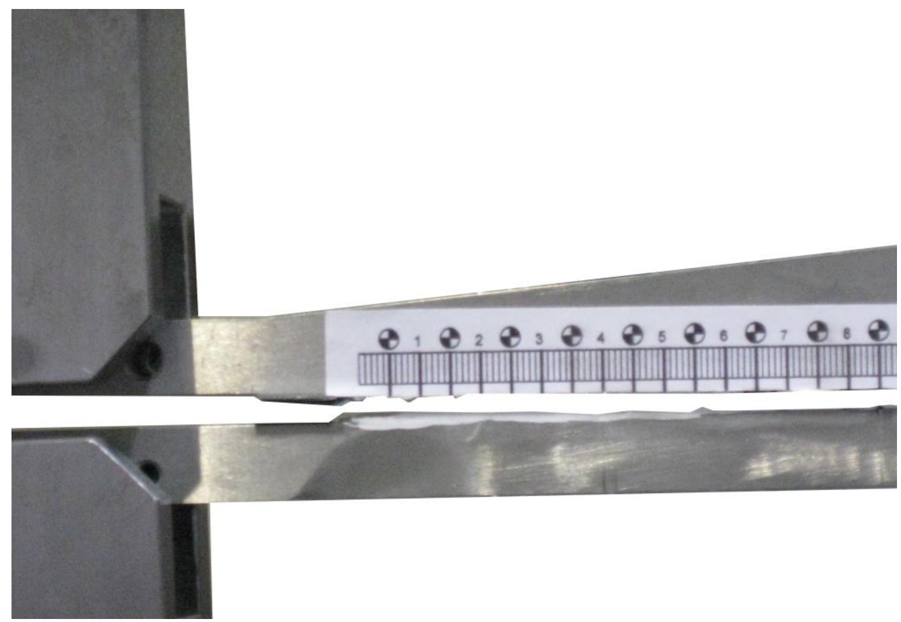


Asymmetrical Tapered Double Cantilever Beam [ATDCB]



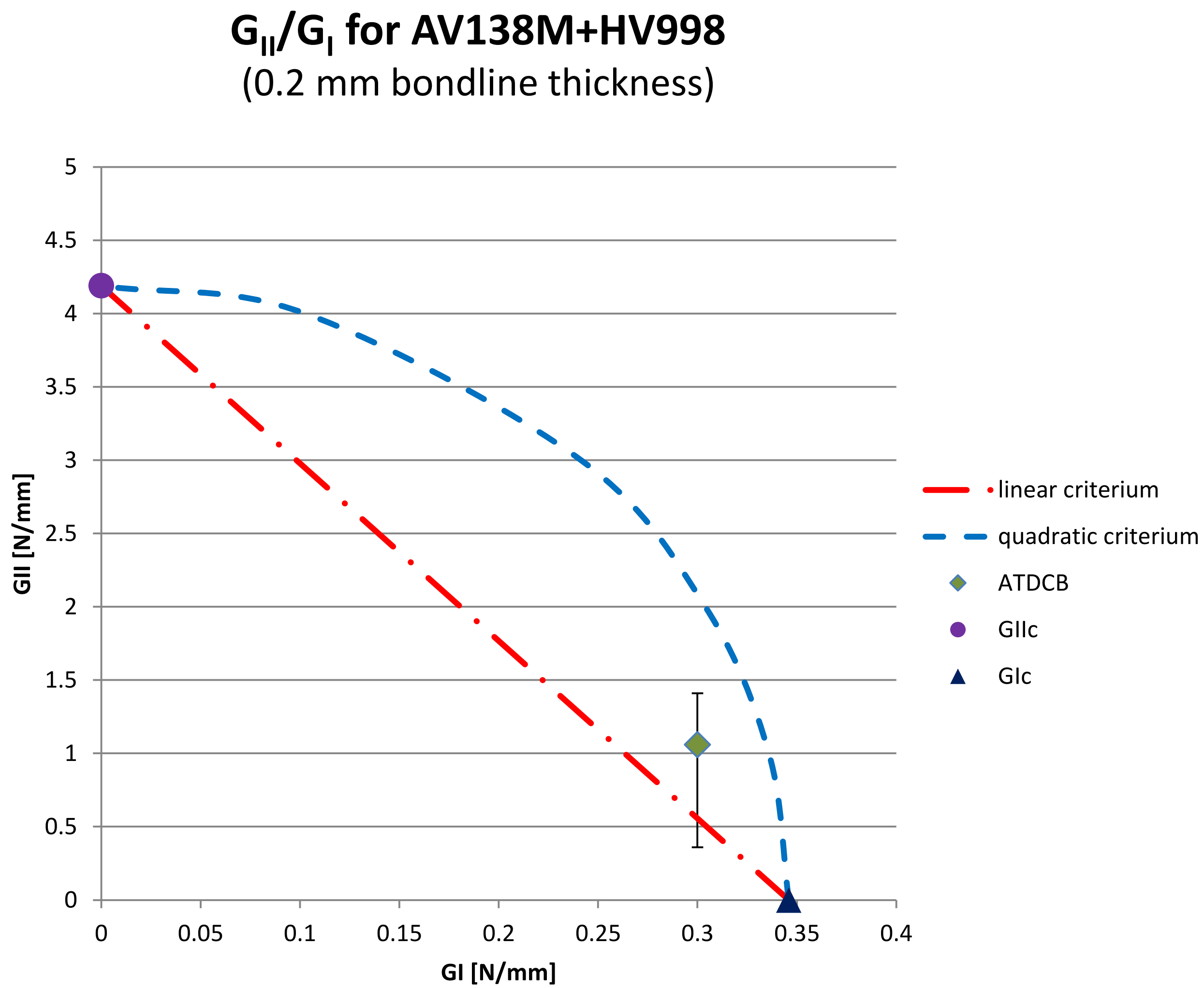
mixed-mode testing

ATDCB

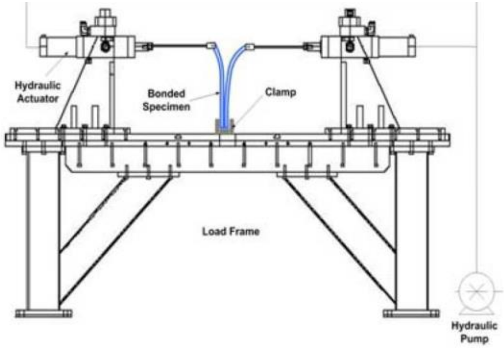


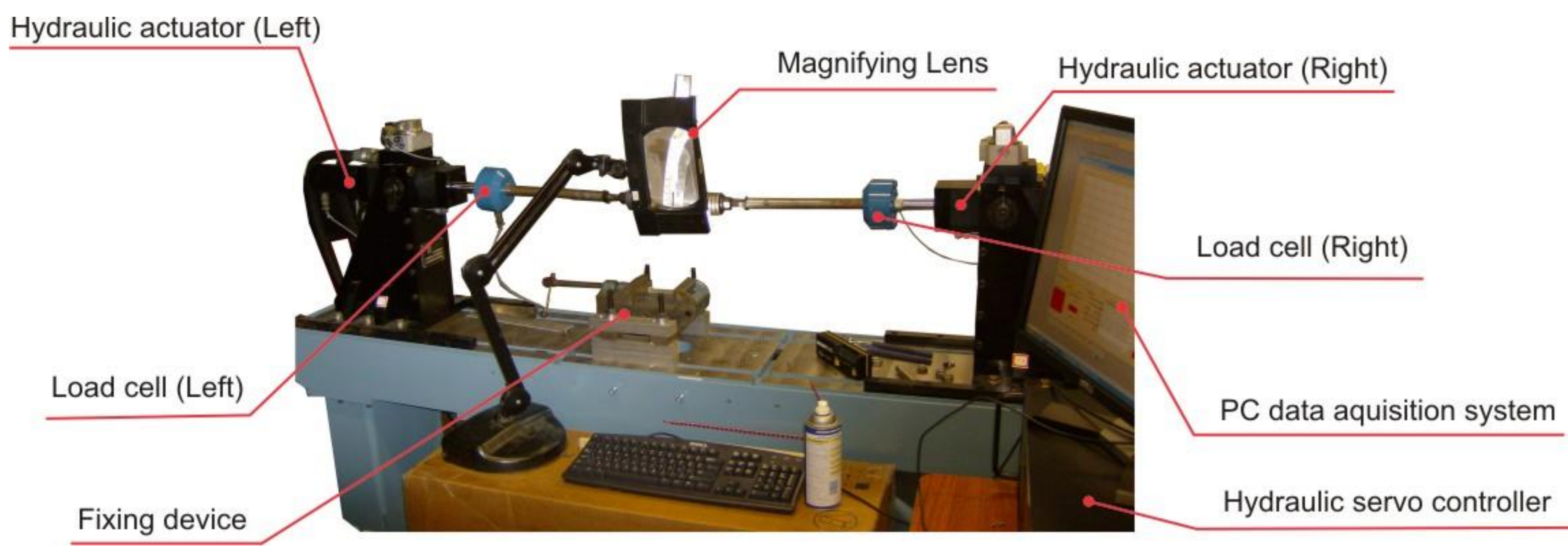
2. Soojae Park · David A. Dillard, Int J Fract (2007), vol 148, pp 261–271

ATDCB

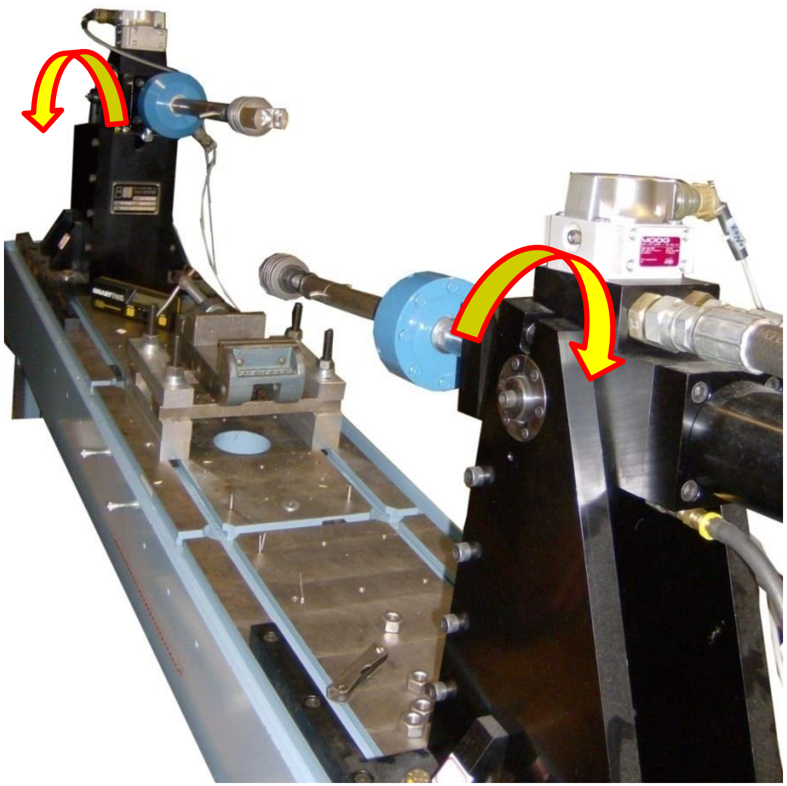

G_{II}/G_{I} for AV138M+HV998
(0.2 mm bondline thickness)
GII [N/mm]
GI [N/mm]
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
linear criterium
quadratic criterium
ATDCB
GIIc
GIc

Virginia Tech's Double Actuator Loading Frame

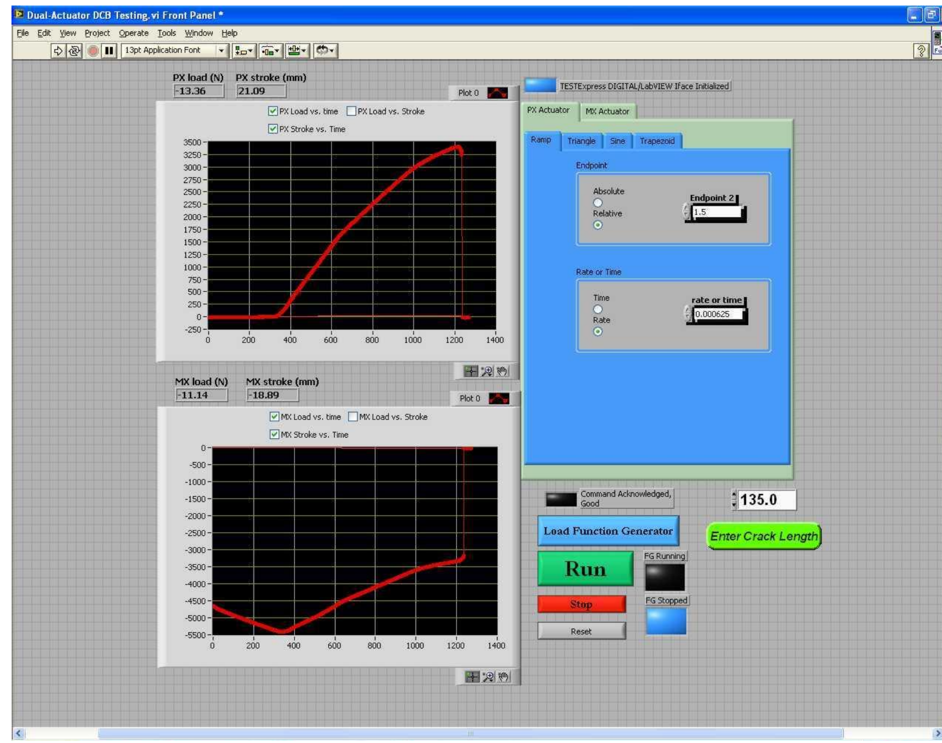




Virginia Tech’s Double Actuator Loading Frame

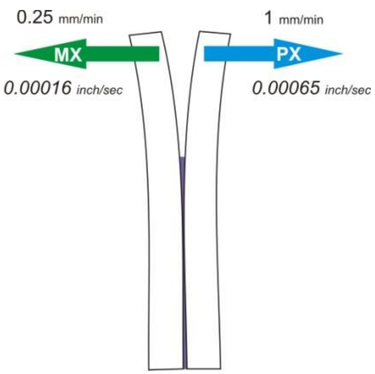


Rotation (detail)

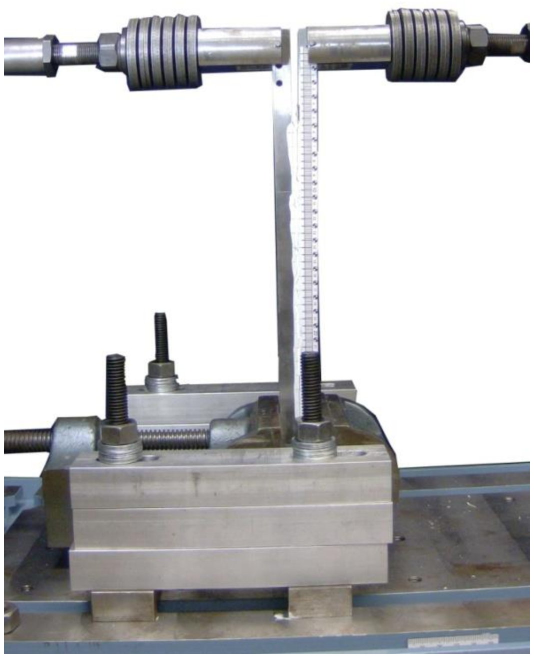


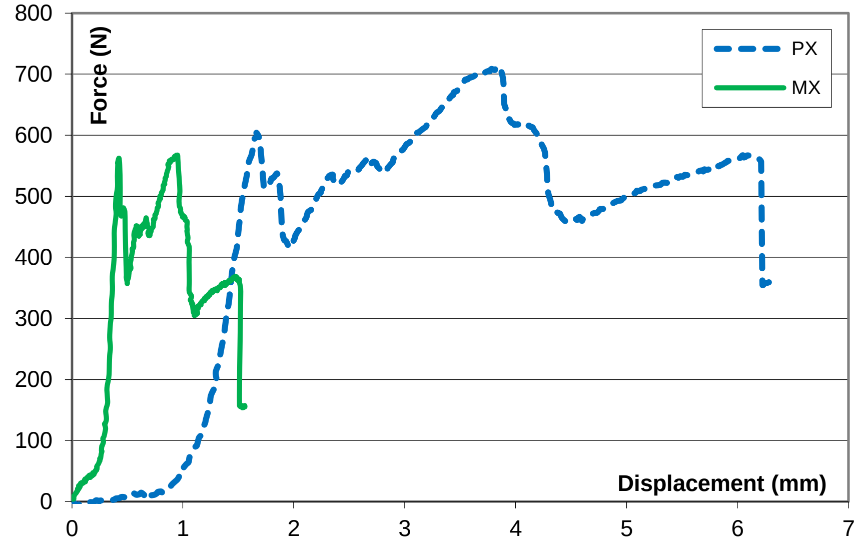
Labview controller

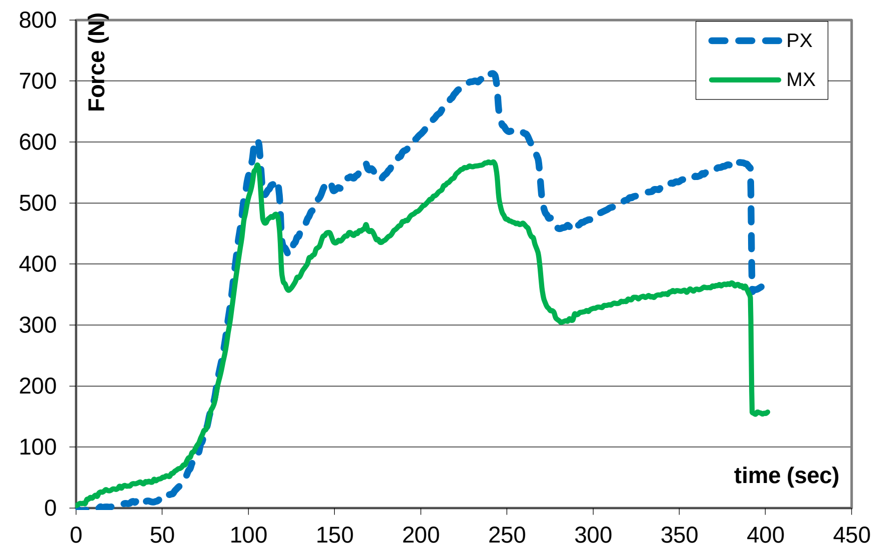
mixed mode testing



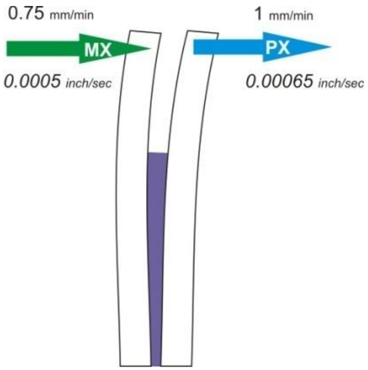
Loading scheme 1



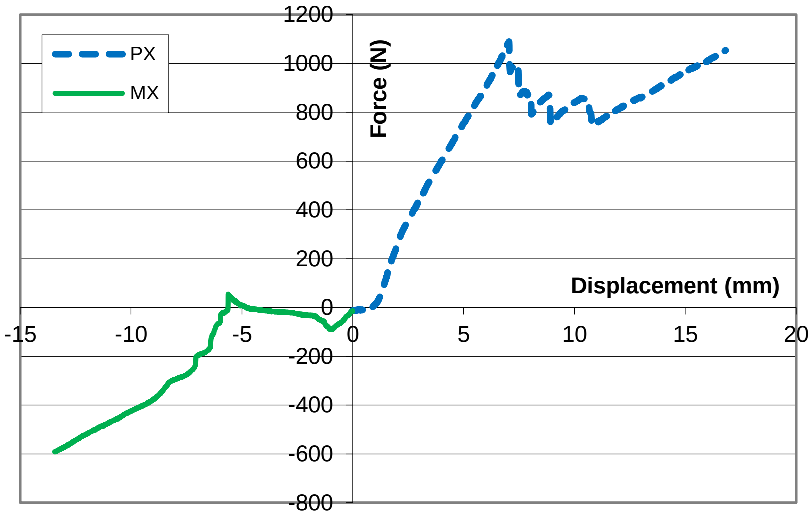


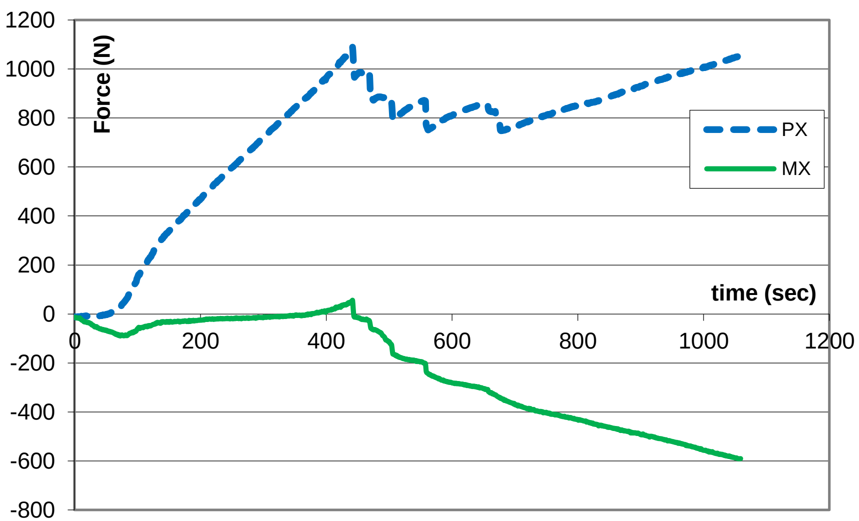


mixed mode testing



Loading scheme 2





data reduction

formulation

Tests are conducted with symmetric DCB specimens and asymmetric displacement rates.
Applied displacements result in a combination of pure mode I and pure mode II loading.
The forces exerted on the two beams are measured by load cells attached to each actuator and the fracture components are calculated with equations 1 and 2, where ***PI*** and ***PII*** are the forces measured by the load cell.

$$P_I = \frac{P_2 - P_I}{2}$$ eq. 1

$$P_{II} = \frac{P_2 + P_I}{2}$$ eq. 2

Values for the energy release rate are obtained with equations 3 and 4, where ***b*** is the width of the bond, ***I*** and ***E*** are the moment of inertia and the elastic modulus of the adherends, respectively, and ***a*** is the crack length .

$$G_I = \frac{12 P_I^2 a^2}{b^2 E h^3} + \frac{6 P_I^2}{5 b^2 h G} = \frac{6 P_I^2}{b^2 h}\left(\frac{2a^2}{h^2 E} + \frac{1}{5G}\right)$$ eq. 3

$$G_{II} = \frac{9 P_{II}^2 a^2}{b^2 E h^3}$$ eq. 4

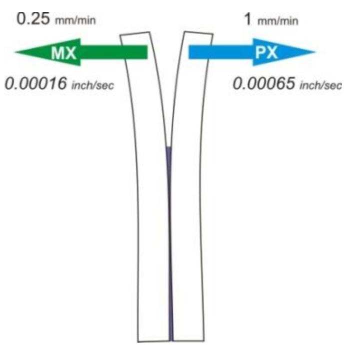
The global mode mixity is then indicated with the angle Ψ defined in equation 5.

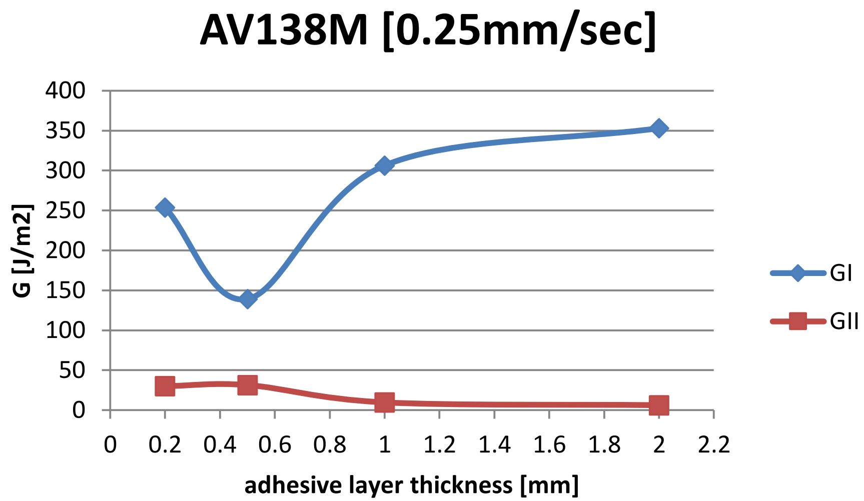
$$\Psi = ArcTan\left(\sqrt{\frac{G_{II}}{G_I}}\right)$$ eq. 5

results

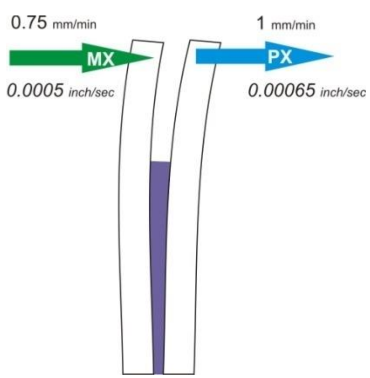
Araldite® AV138M + HV998

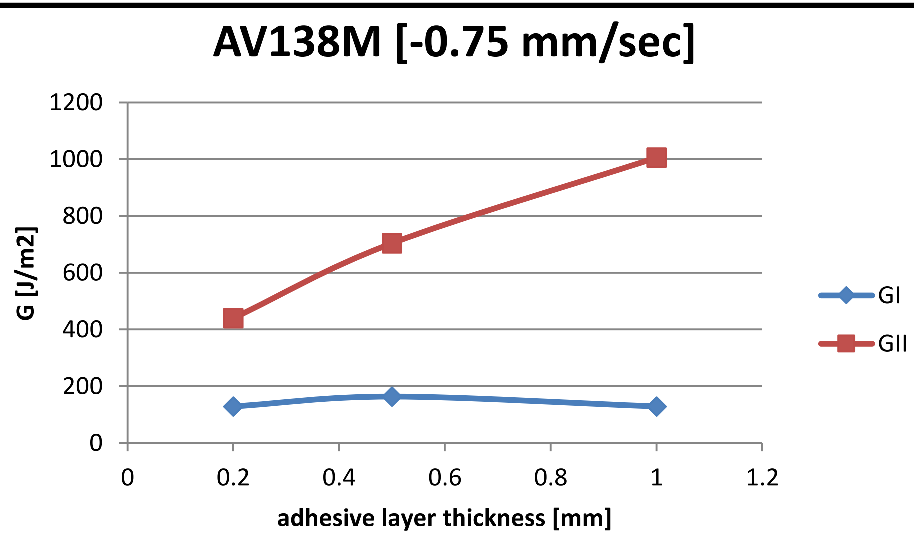
Loading scheme 1





Loading scheme 2

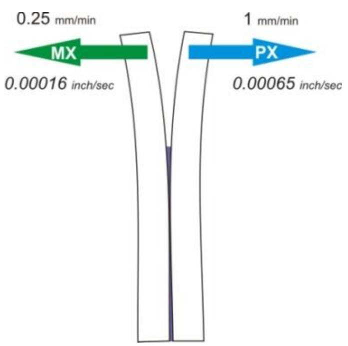


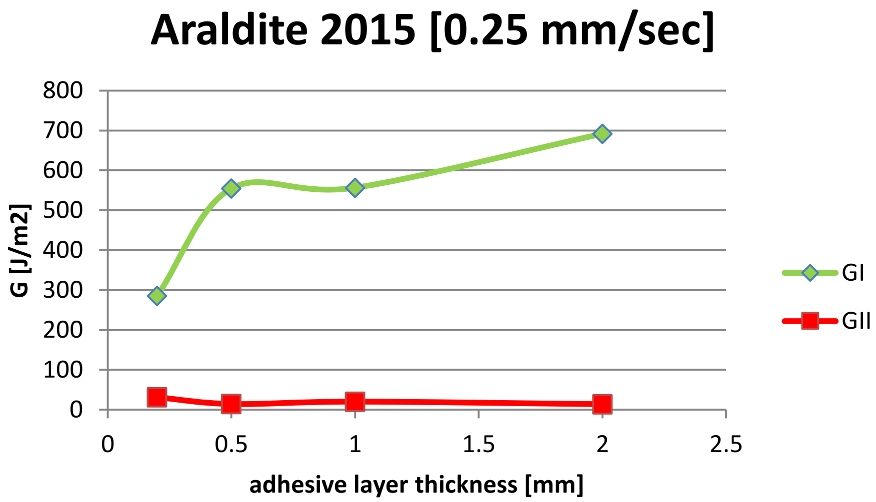


results

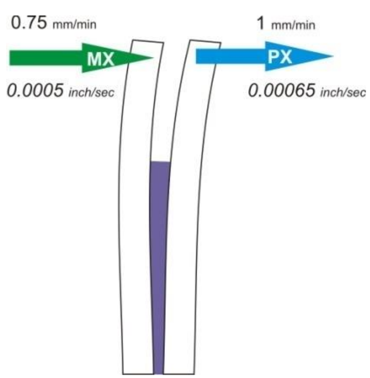
Araldite® 2015

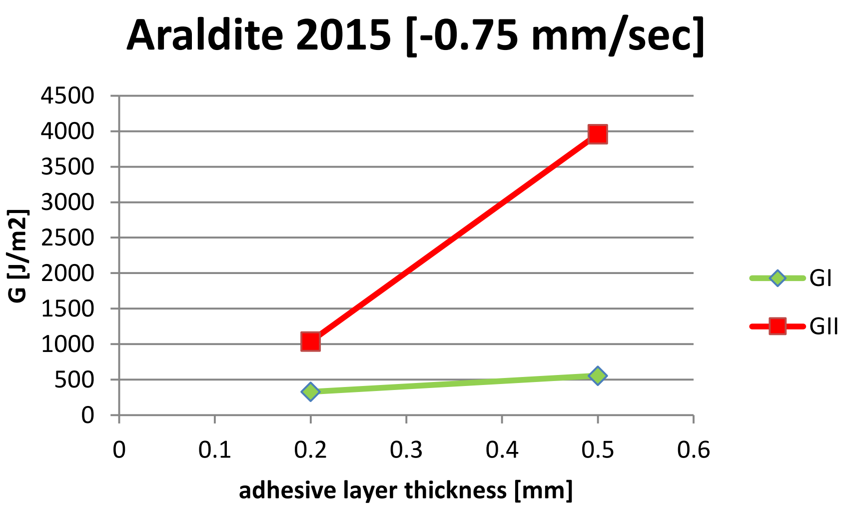
Loading scheme 1





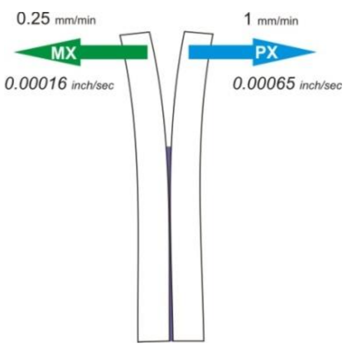
Loading scheme 2

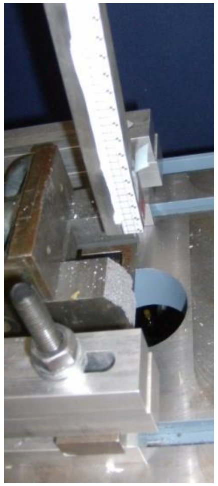




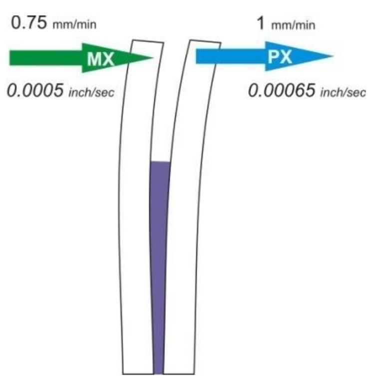
SIKAflex® 255 FX

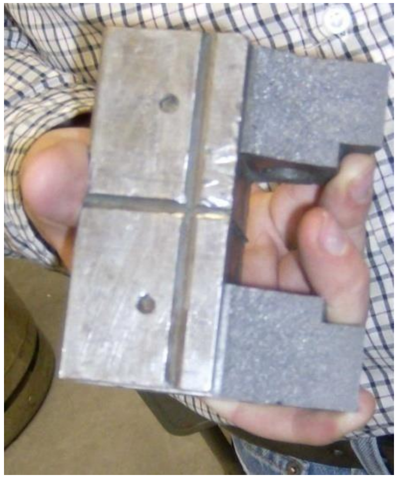
Loading scheme 1

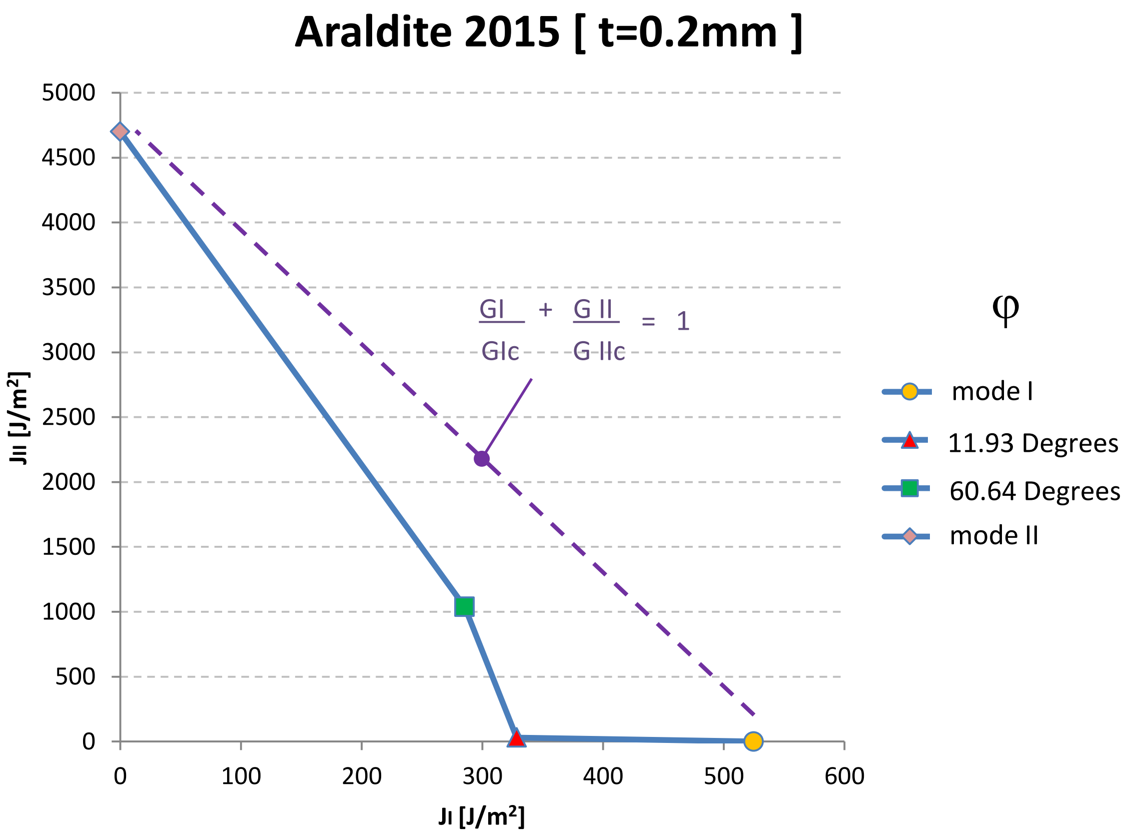




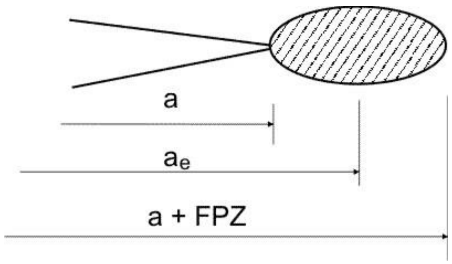
Loading scheme 2






Araldite 2015 [t=0.2mm]
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
JII [J/m2]
0
100
200
300
400
500
600
JI [J/m2]
GI + G II = 1
GIc G IIc
φ
mode I
11.93 Degrees
60.64 Degrees
mode II

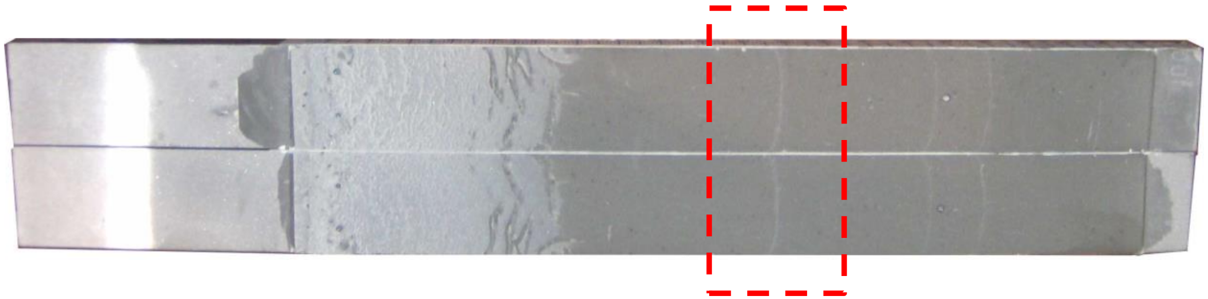
Compliance Based Asymmetrical Beam Method [CBABM]

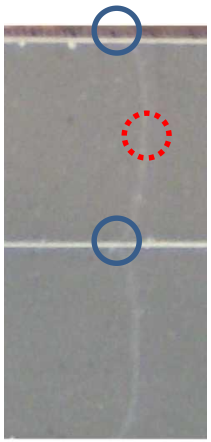


Usage of measured crack length, comprises two problems:

i. The accuracy of measurement at the crack tip is not an easy task;

ii. It dos not account for the fracture process zone [FPZ].





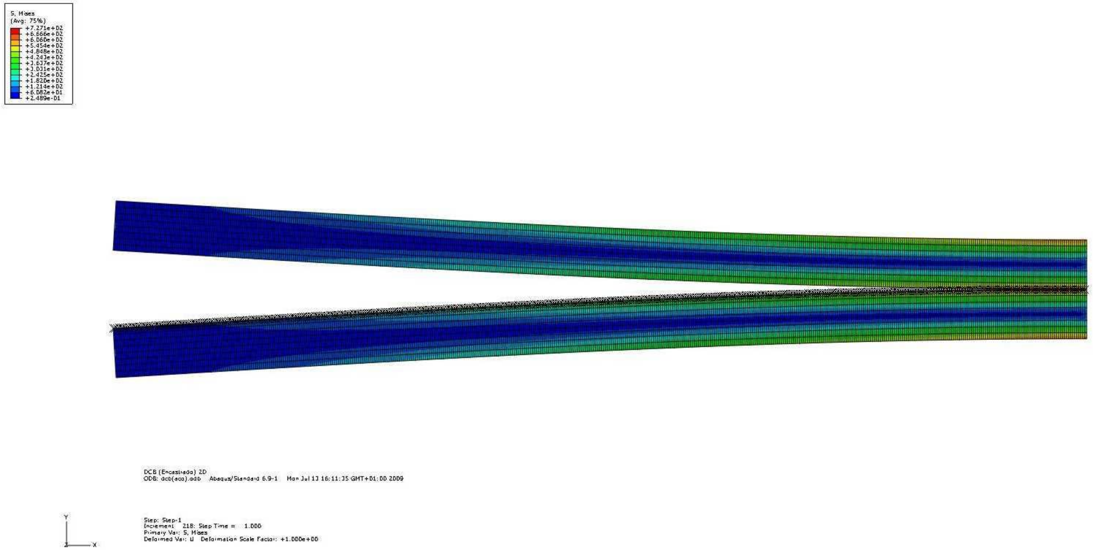
Trying to overcome these problems and improve the results accuracy, na equivalent crack length as defined by Oliveira et al. [1], should be used in equation 3 and 4.

$$G_I = \frac{12P_I^2 a_{eq}^2}{b^2 E h^3} + \frac{6P_I^2}{5b^2 h G} = \frac{6P_I^2}{b^2 h}\left(\frac{2a_{eq}^2}{h^2 E} + \frac{1}{5G}\right)$$

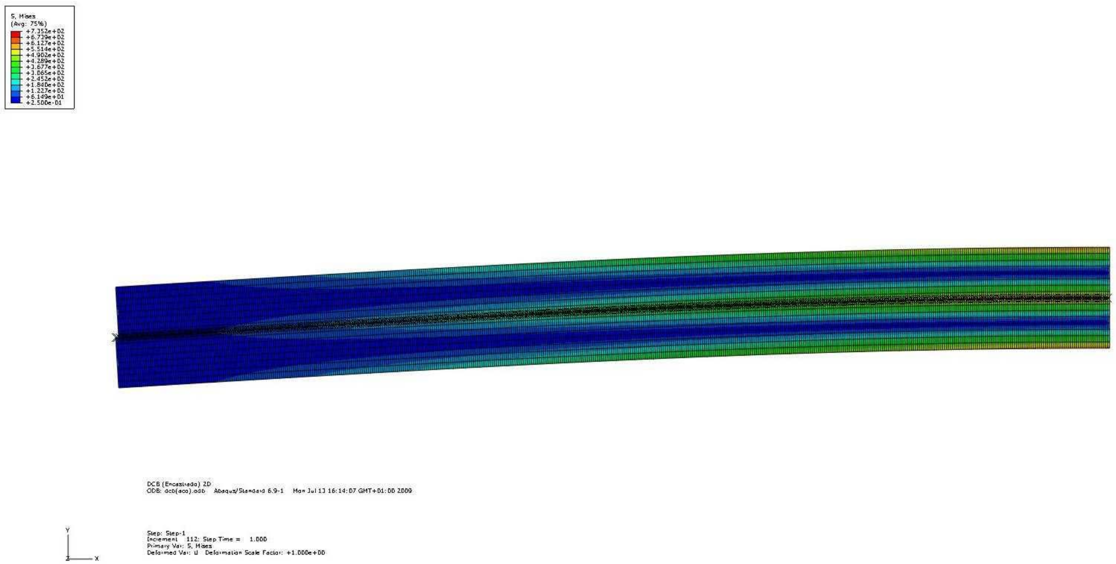
$$G_{II} = \frac{9P_{II}^2 a_{eq}^2}{b^2 E h^3}$$

1. Oliveira, J.M.Q., de Moura, M.F.S.F., Silva, M.A.L., Morais, J.J.L., wood fracture Composites Science and Technology Vol.67 (9), 2007, pp. 1764-1771

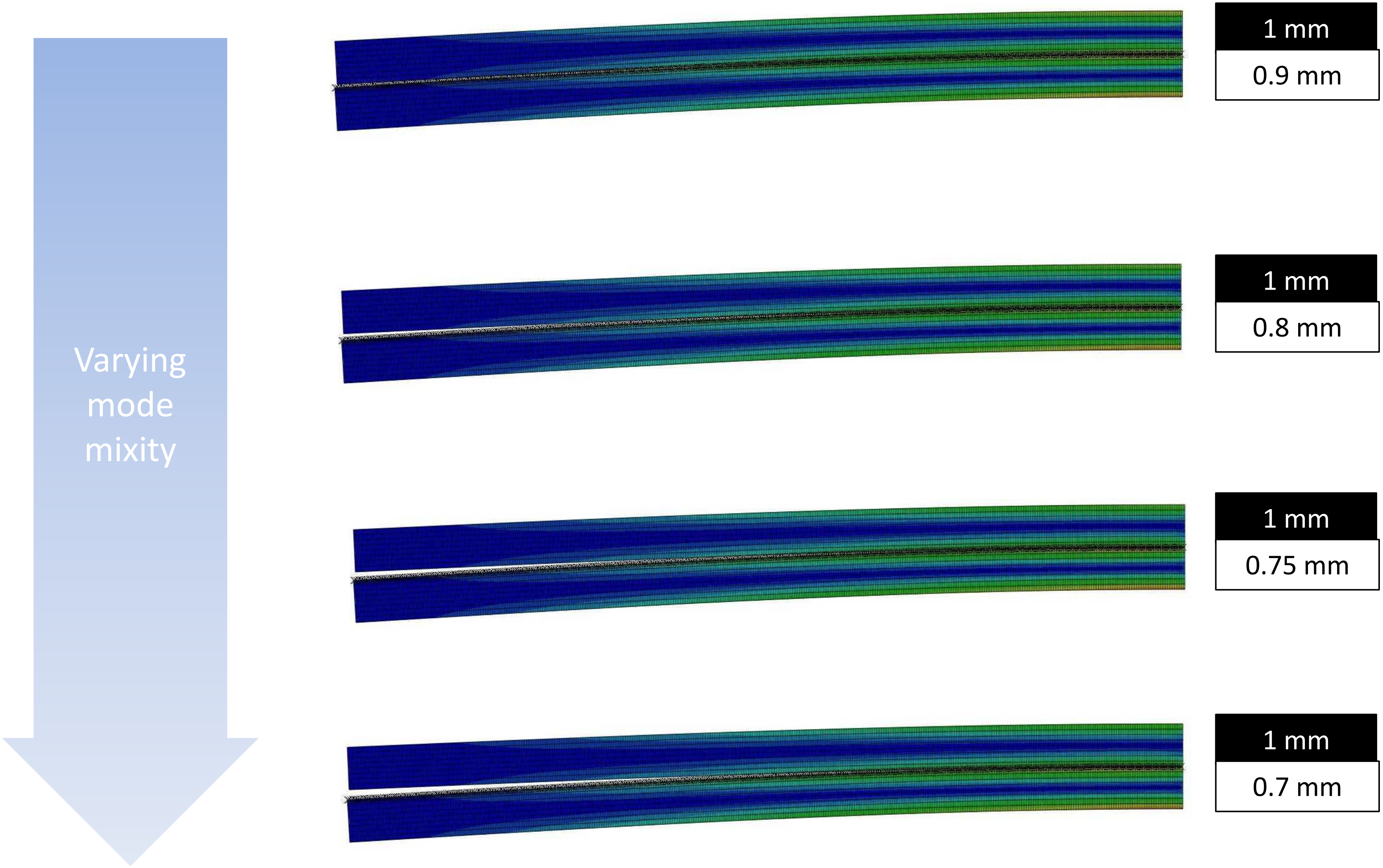
Mode I Loading



Mode II Loading



Tuning and setup

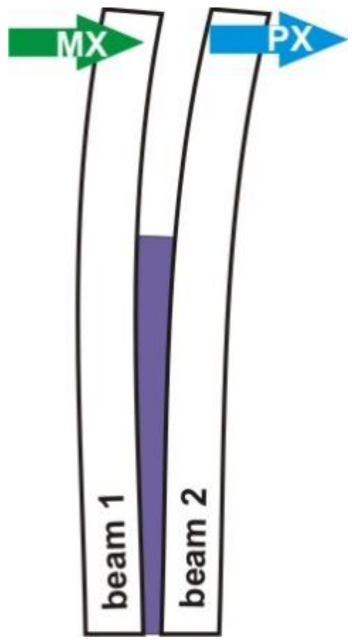


Tuning and setup

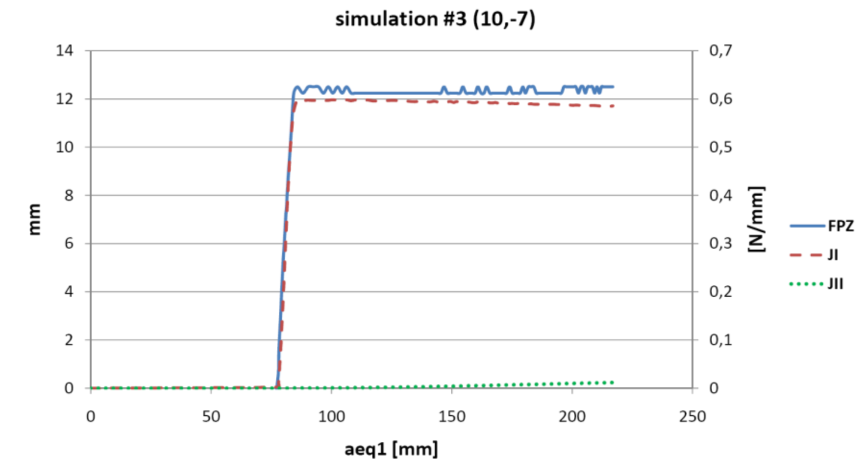
imposed:

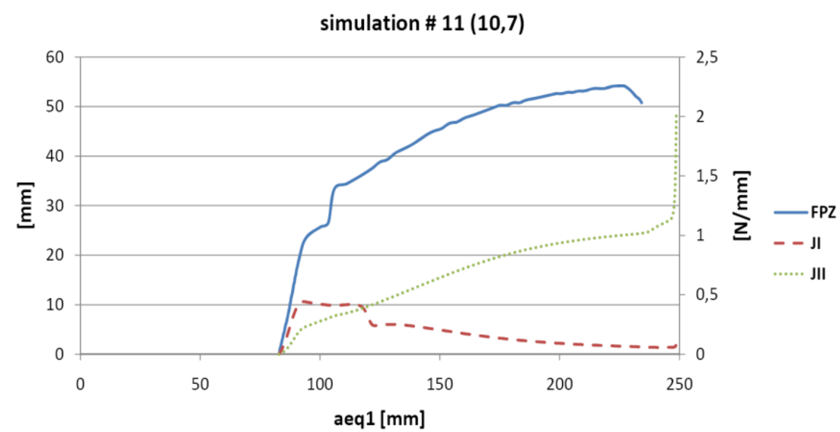
$$J_I = 0.6\ \text{N/mm}$$

$$J_{II} = 1.2\ \text{N/mm}$$

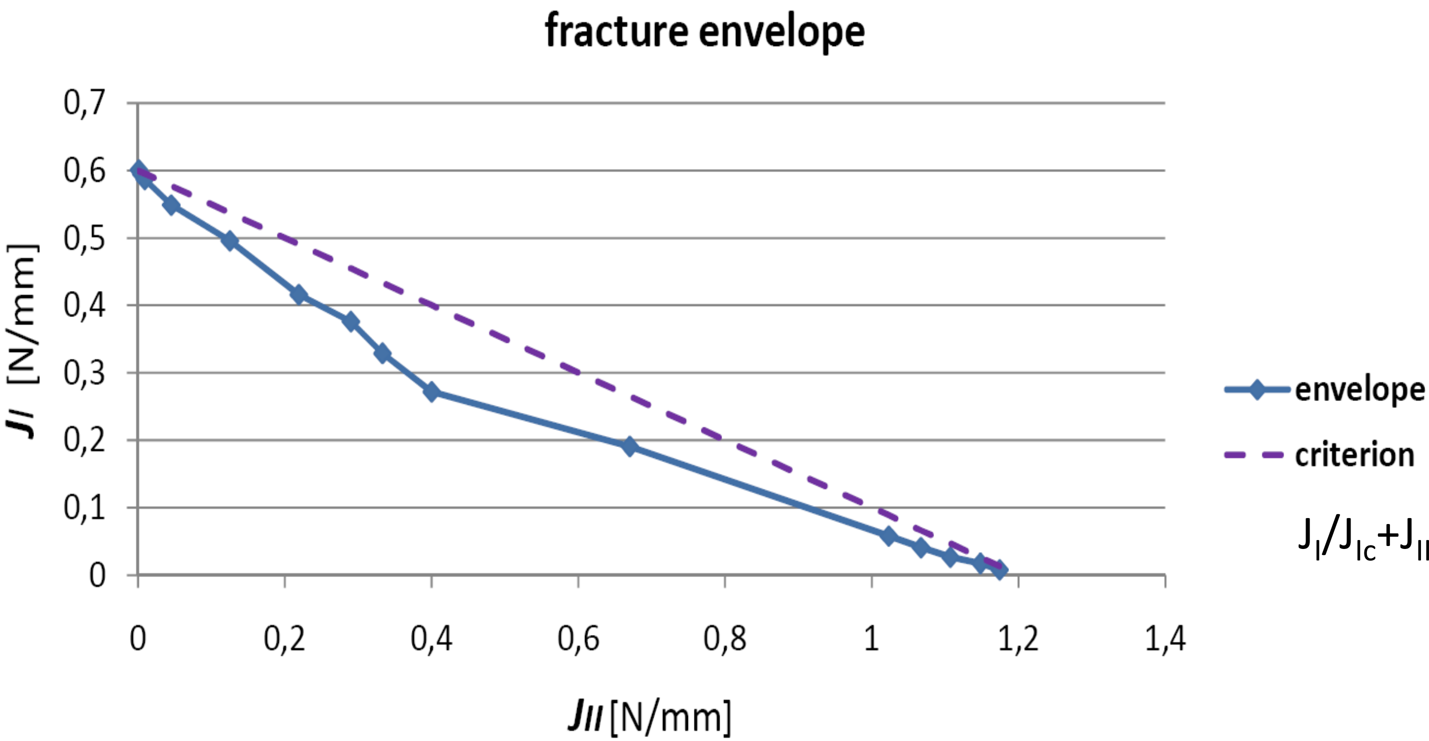


	imposed displacem.	
Simul.	beam 1	beam 2
1	10	-9
2	10	-8
3	10	-7
4	10	-5
5	10	-3
6	10	-1
7	10	0
8	10	1
9	10	3
10	10	5
11	10	7
12	10	7.5
13	10	8
14	10	8.5
15	10	9





Tuning and setup



$J_I/J_{Ic}+J_{II}/J_{IIc}=1$

conclusions

The study focused on the mode mixity that results from the superposition of fracture modes I and II

The dual-actuator load frame is a testing machine that allows to characterize thoroughly the mixed mode fractures just carrying tests on DCB specimens constructed with symmetric beams, simplifying the specimen construction.

Although the crack length measurement was used, it can be improved by calculating an equivalent crack length, accounting for the FPZ effect.

Adhesive layer thickness affected both mode I and mode II by increasing GI and GII respectively for each governing loading scheme.

The aim of this undergoing project is the development of fracture envelopes for different adhesives and thicknesses. These envelopes can be useful in designing adhesive joints and contributing to design a mixed mode bending test apparatus based on the Reeder Crews MMB delamination apparatus or a Spelt Mixed Mode fixture.

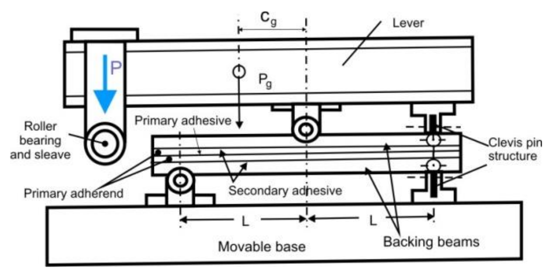
next step

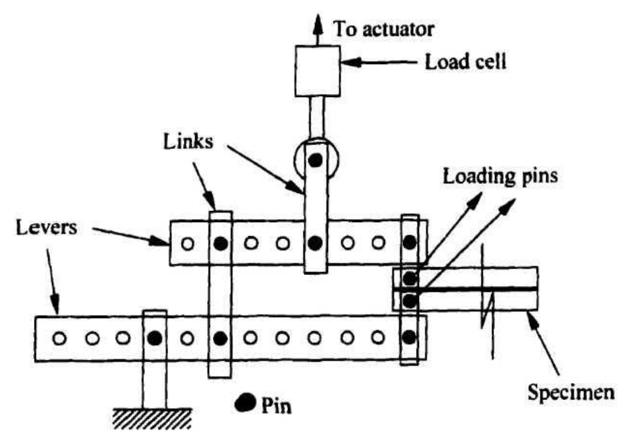
a Apply the CBABM to the experimental data, hoping to obtain better results.

b Finish ATDCB (Asymmetric Tapered Double Cantilever Beams) [2] to characterize the remaining adhesives and thicknesses for the envelope ($\Psi \cong 20°$);

c To do some SLB tests to gather more data for the envelope ;

d With the data collected, design an apparatus similar to the one of Reeder and Crews [3] or Spelt [4], to obtain more points with different mode-mixities in order to improve the fracture envelope for different adhesives and different thicknesses.





2. Soojae Park · David A. Dillard, Int J Fract (2007), vol 148, pp 261–271
3. Reeder JR, Crews JH, AAIJ 1990;28(7):1270-6
4. Fernlund G, Spelt JK. Compos Sci Technol (1994), vol. 50 pp. 441–449

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Thank you !!

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