DEVELOPMENT AND EVALUATION OF A SELF-REPAIRING CONCEPT FOR COMPOSITE MATERIALS.

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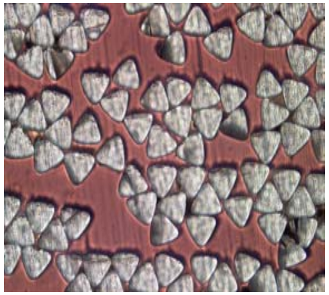
Department of Aerospace Engineering

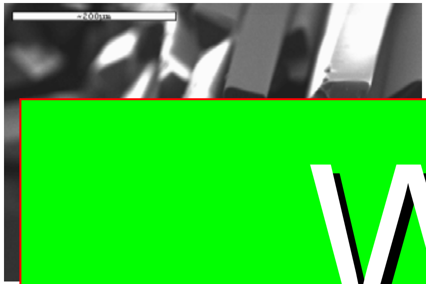
Overview

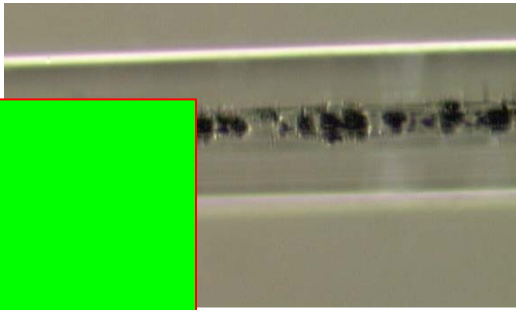
- Background
- Why self-repair?
- Possible Approaches
- Chosen Approach
- Experimental
- Results
- Modelling
- Conclusions
- Ongoing/Further Work

Background – Ongoing Fibre Work at Bristol

50μm triangular fibres



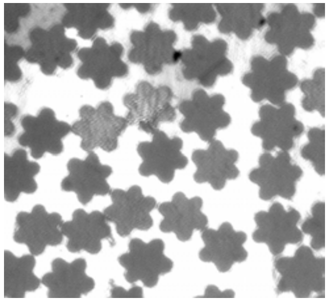




agnetic fibres

WHY SELF-REPAIR?

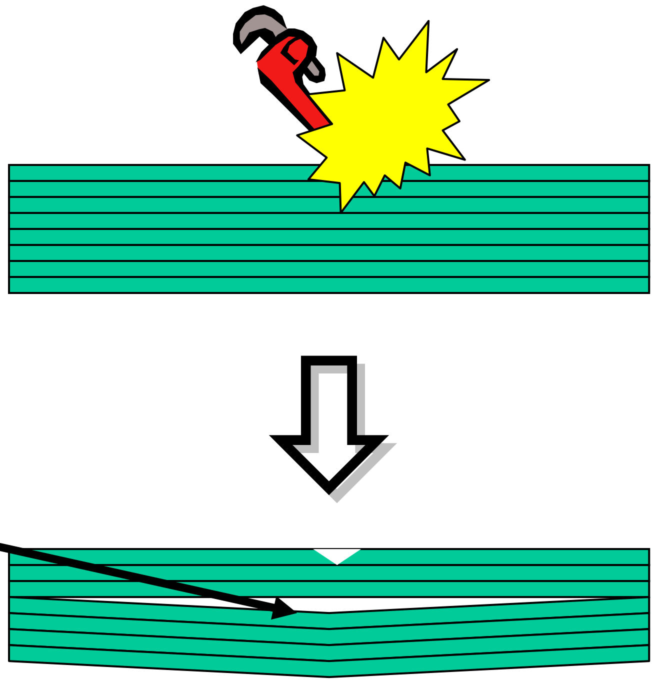
pairing fibres



50μm star shaped fibres

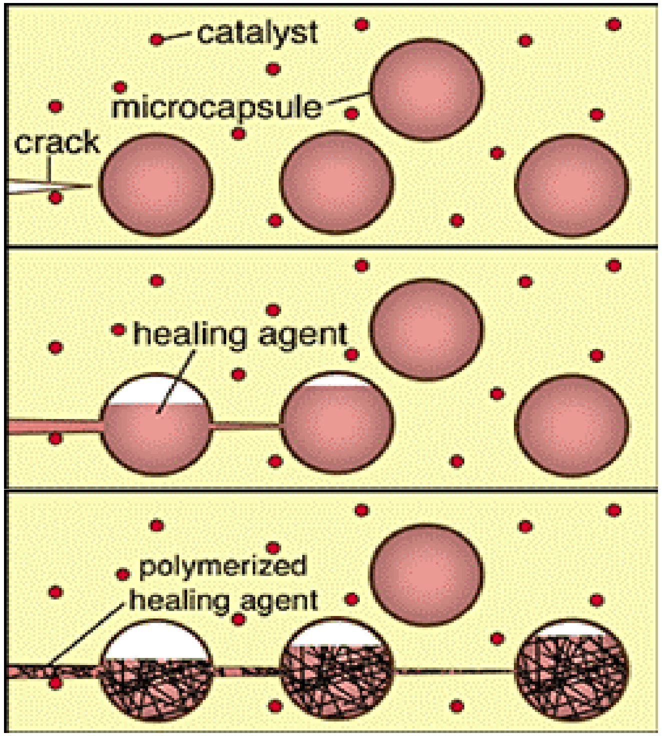
Damage Susceptibility

- Continuous fibre reinforced plastics - 2D ply structure
- Excellent in plane properties
- <u>BUT</u> susceptible to 'delamination' after a damage event!
- Minor external, major internal damage

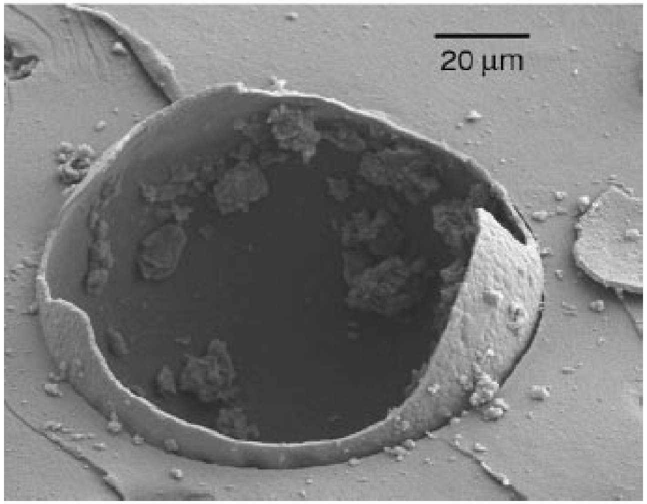


Self-Healing / Self-Repair

Possible Approach: Microencapsulation



(a)

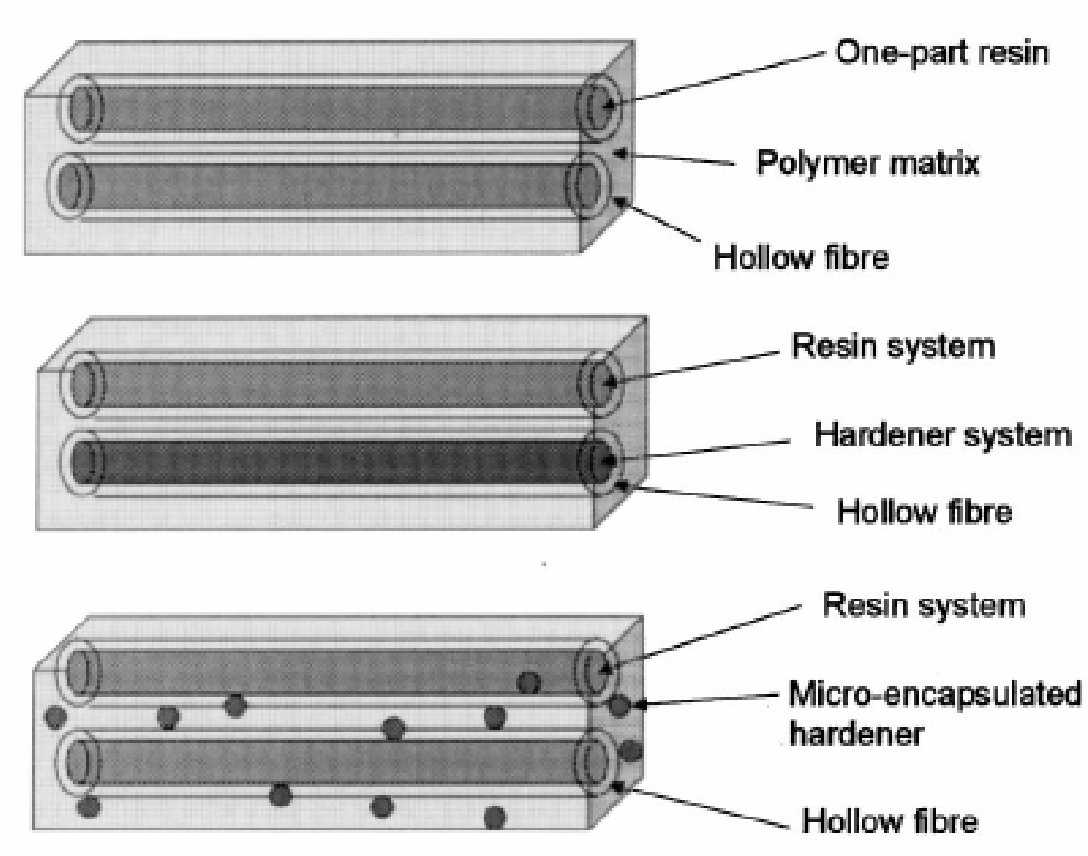


(b)

(a) Basic method of the microcapsule approach, (b) ESEM image showing ruptured microcapsule

S.R. White et al. Nature. 2001 409, 794-797.

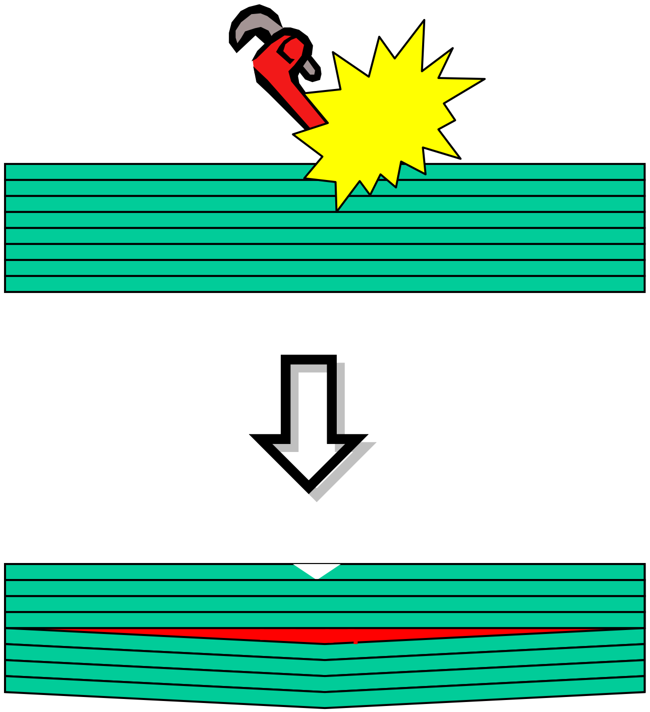
Possible Approach: Hollow Fibres



Possible approaches for FRP's

Chosen Approach

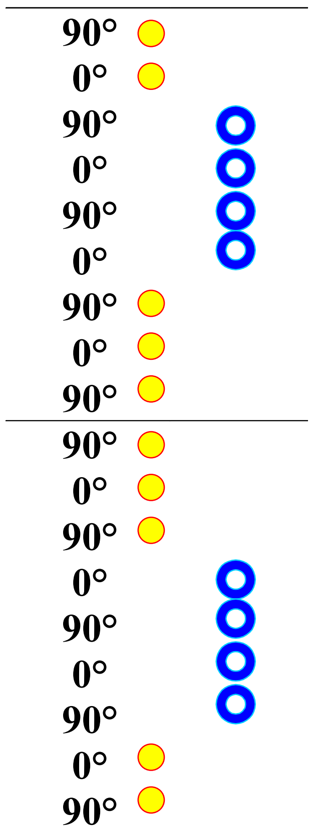
- **Objectives:**
- **Develop a FRP which employs a biomimetic approach to perform a self-repair function**
- **Restore mechanical strength by self-activated, self-repairing process**
- **Enhance damage visualization by the bleeding action of highly conspicuous media**



Experimental Approach

- Hollow glass fibre used for storing functional components
- Sandwich of Hollow Fibre & Solid E-glass with epoxy
- Damage created by indentation
- Healing process investigated under different conditions prior to 4-point flexural testing

Lay up Configuration



Solid E glass/913 epoxy

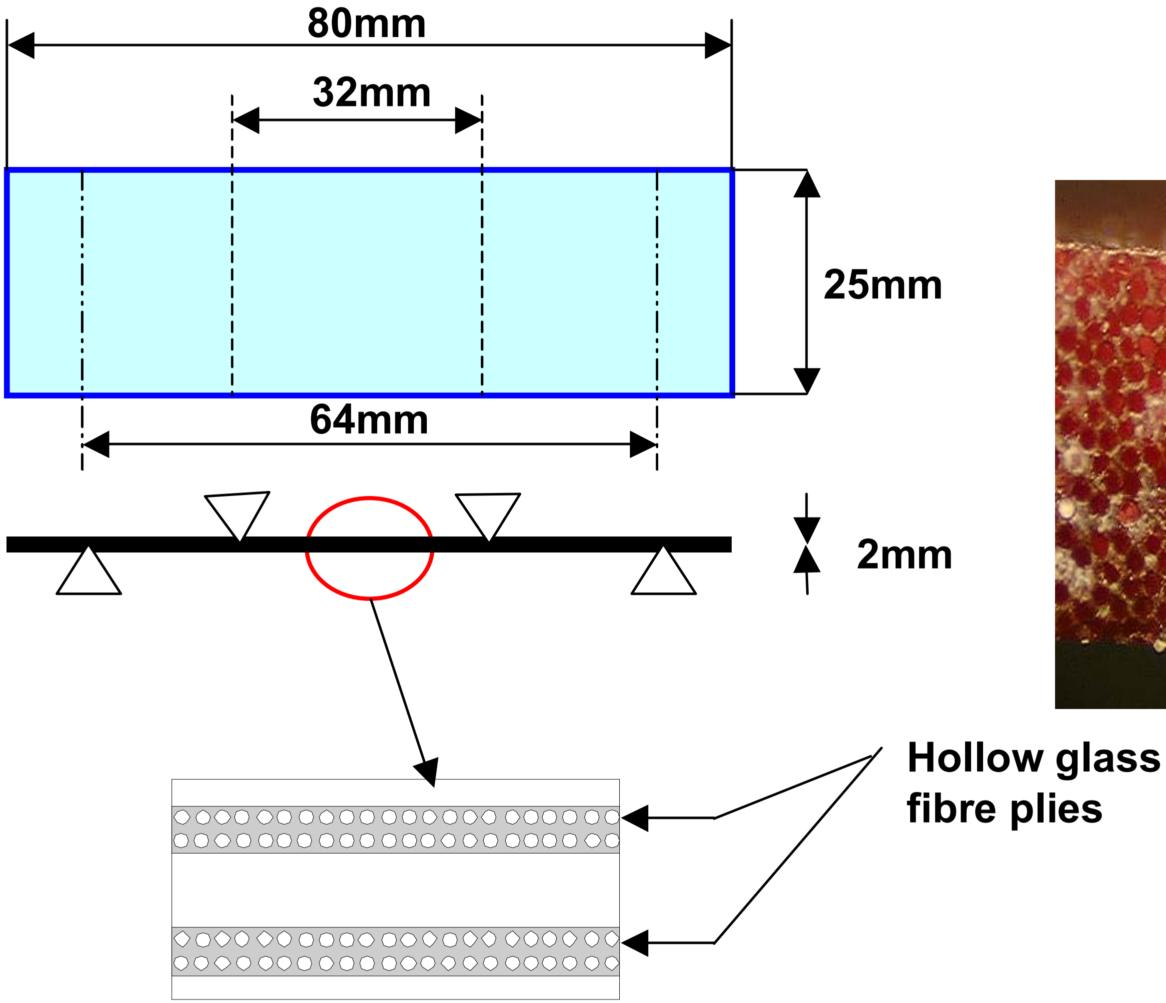
Hollow glass/913 epoxy (60μm/50% hollow)

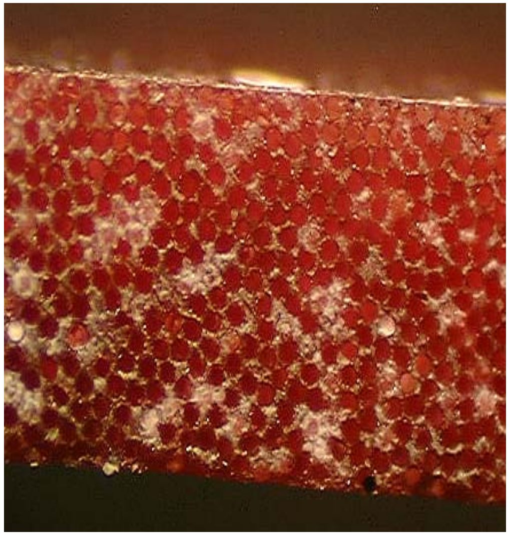
0° - MY750 epoxy resin + 20% acetone + fluorescent dye

90° - Hardener

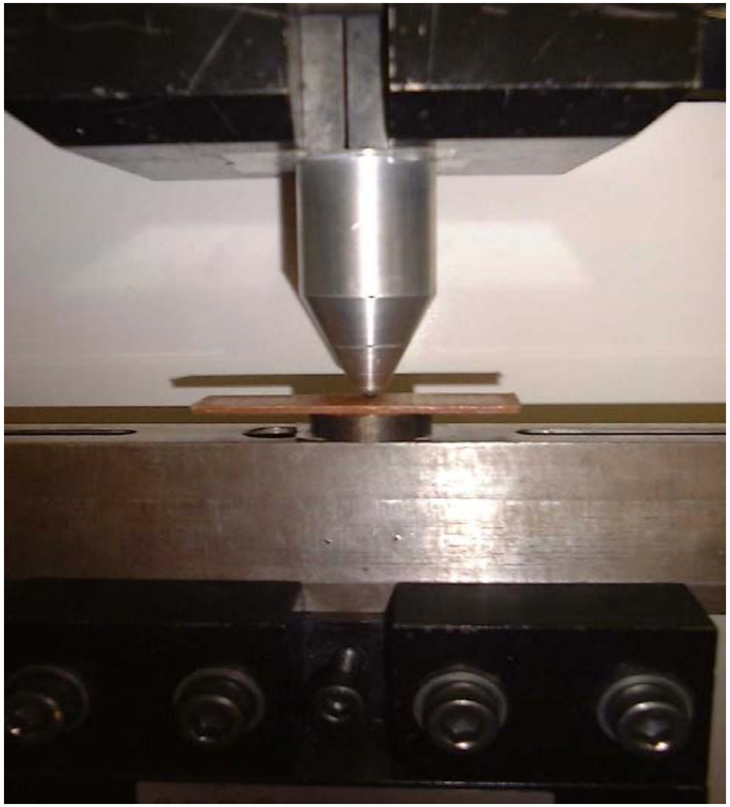
$$\{[90°/0°]_{(solid)},[90°/0°/90°/0°]_{(hollow)},[90°/0°/90°]_{(solid)}\}_s$$

Test Specimen (ASTM-790M-93)

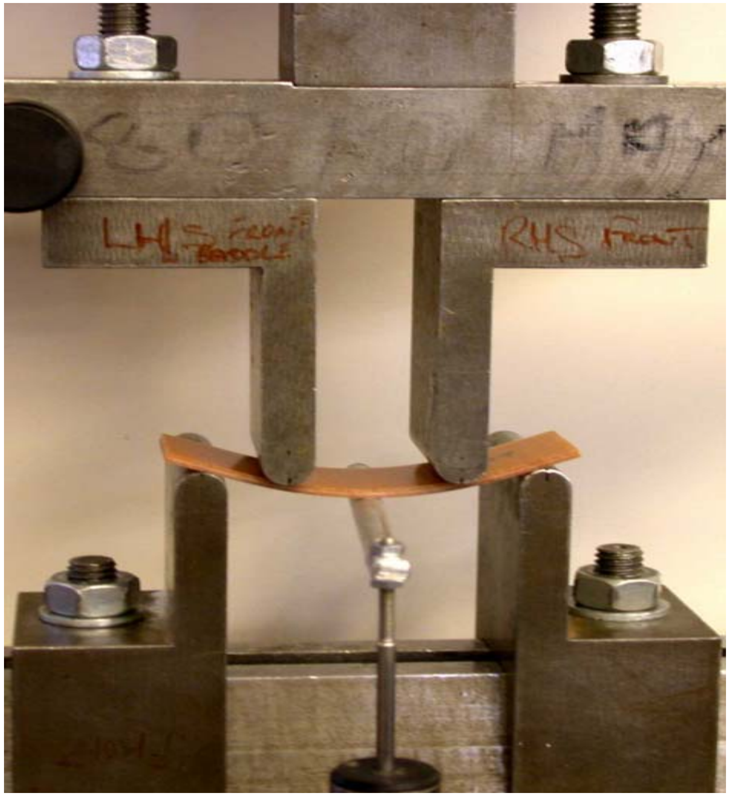




Mechanical Testing

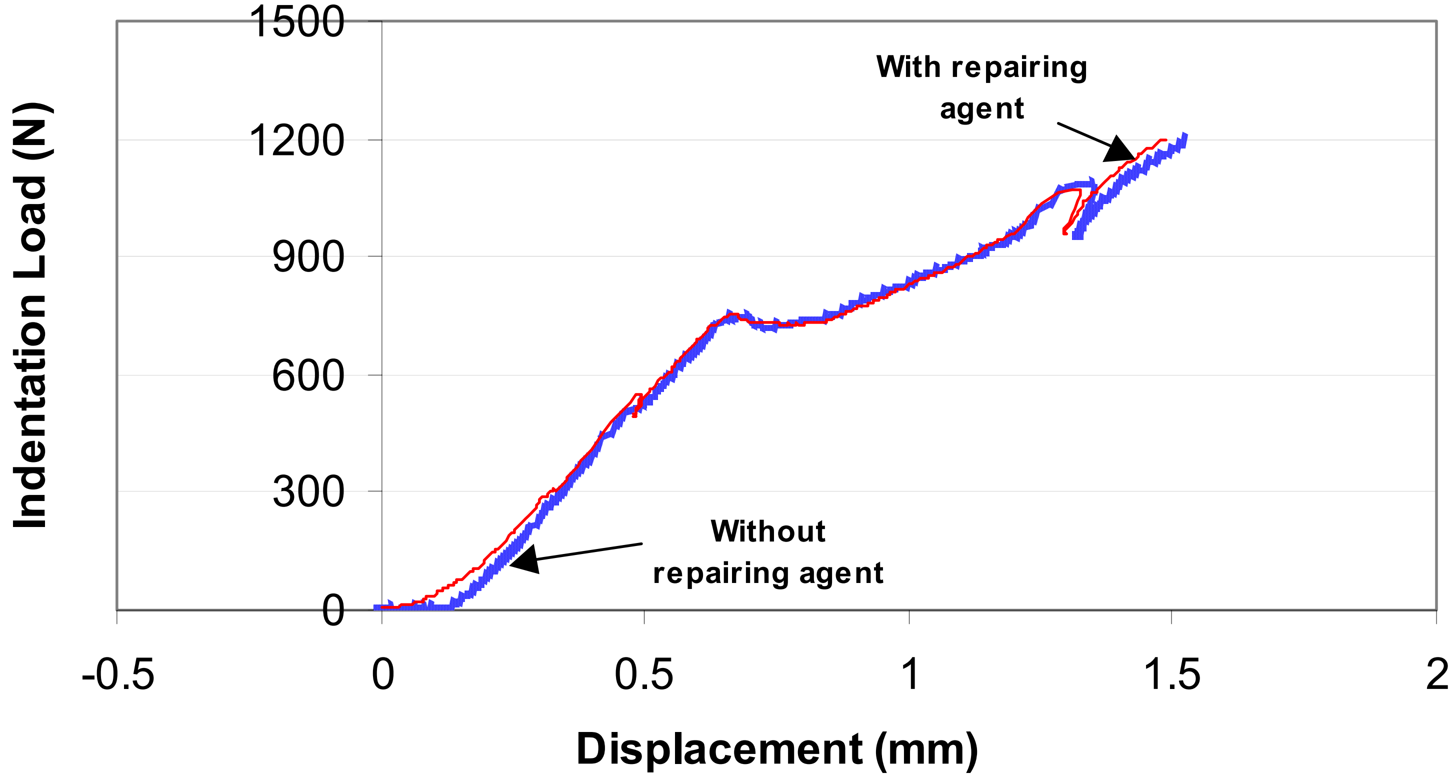


Indentation test fixture

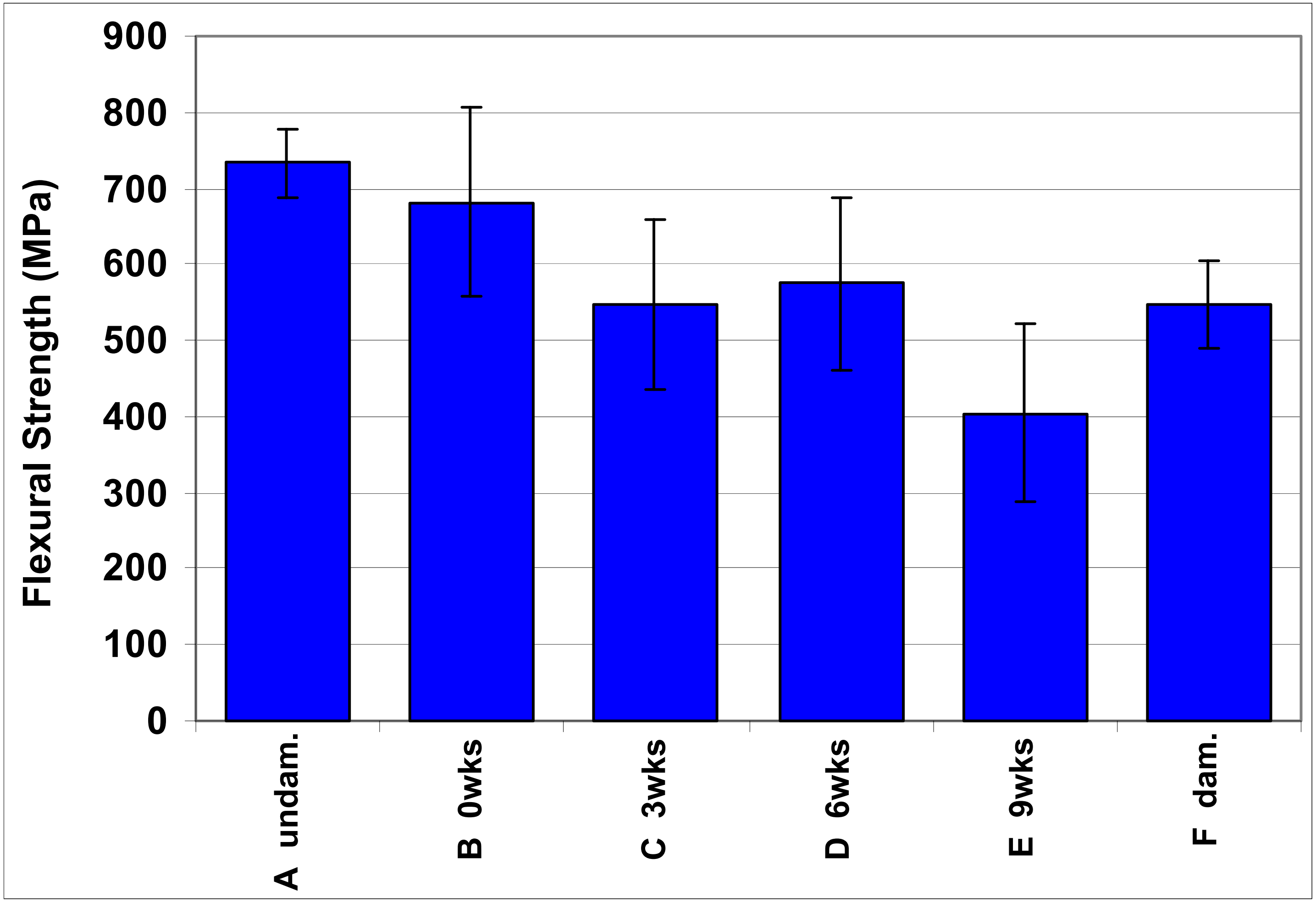


4-point bending test

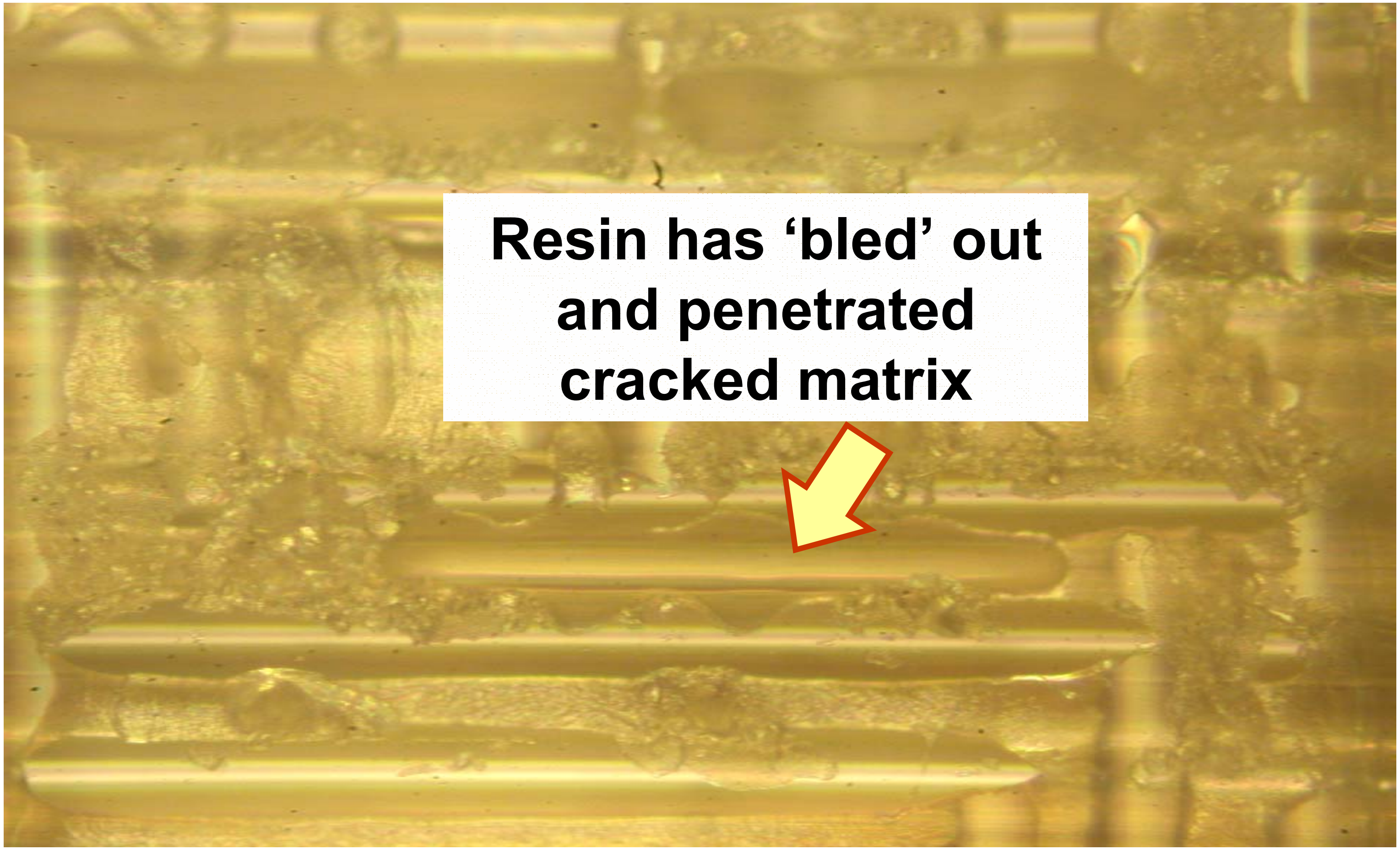
Typical Load-Displacement Curves During Indentation To Create Damage Site



4-Point Bend Testing of Undamaged, Damaged and Self-Repaired Specimens



Cross-Section Through Hybrid Hollow/Solid Glass/Epoxy Laminate.



Modelling

- Urgently needed but NOT trivial!
- Understand/predict (impact!) damage type/location
- Where to place fibres/repair plies for maximum benefit
- Model healing/repair mechanism – improve!

Conclusions

- Self-repair ability demonstrated - significant fraction of flexural strength restored after damage
- Repair efficiency decreases over time
- Problems to be addressed;
  – Optimise location of hollow fibre plies within laminate for maximum benefit – damage specific!
  – Select/tailor resins to improve repair, environmental stability/longevity.
  – Supply/replenishment of repair resin

Ongoing/Further Work

- European Space Agency – investigation application to space environment
- EPSRC - *'Bleeding Composites' - Damage Detection And Self-Repair Using A Biomimetic Approach*
- Collaboration with UIUC (Scott White et al.)

Questions?