

The link between NDT and structural integrity: potential impacts on regulations

Janice Dulieu-Barton

Ole Thomsen, Daniel Bull, Kate Devereux (UoS)

Kevin Potter, Robert Smith (University of Bristol)

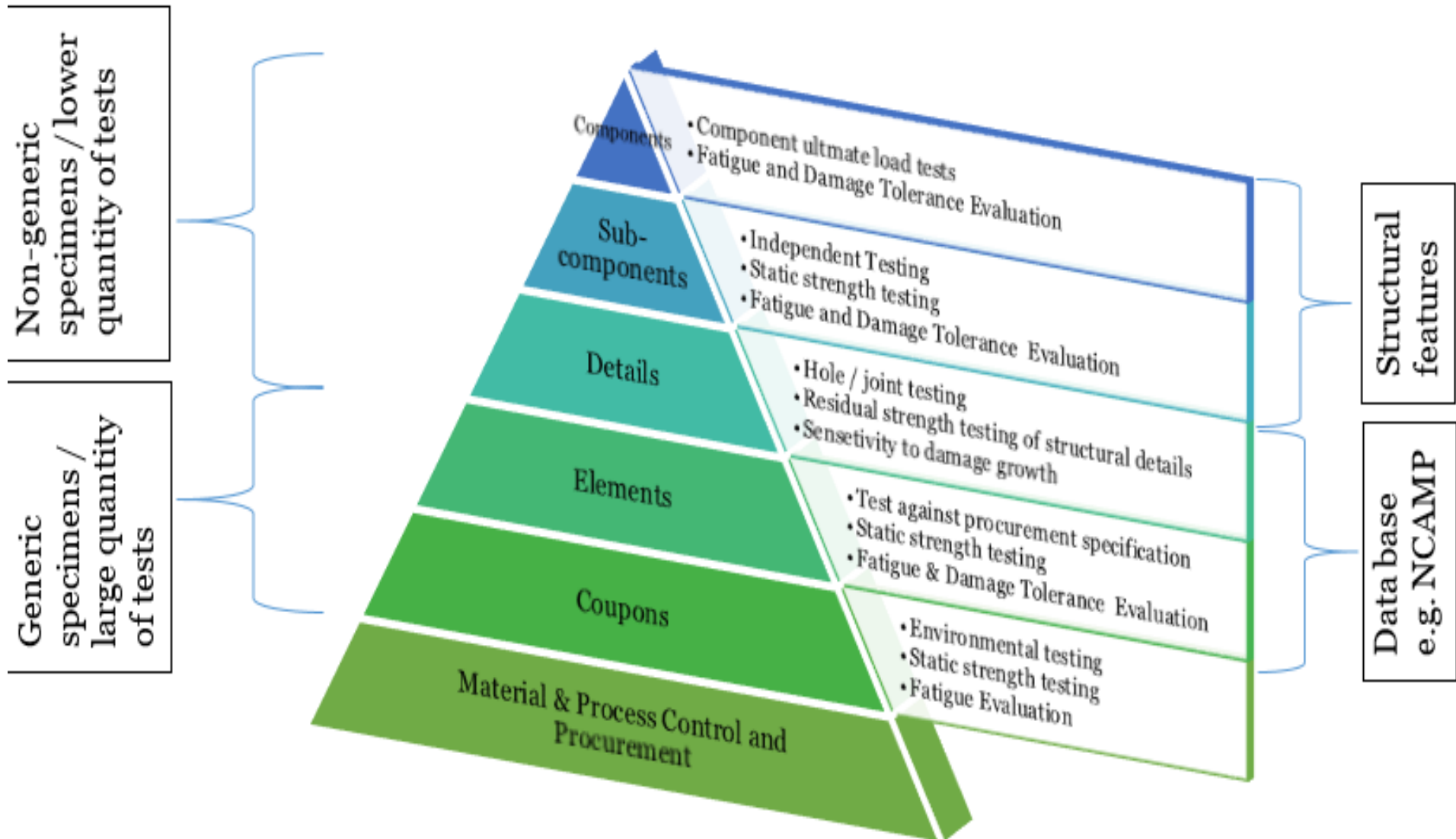
Richard Butler, Andrew Rhead (University of Bath)

Modernising Composite Regulations

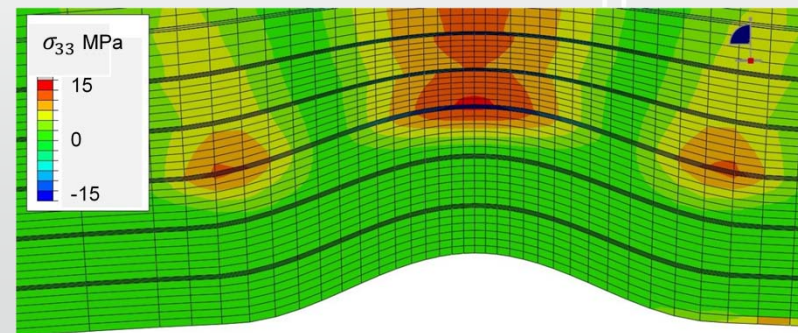
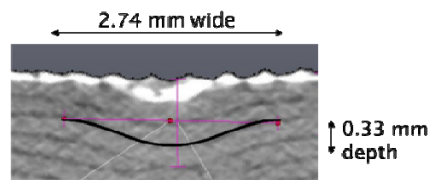
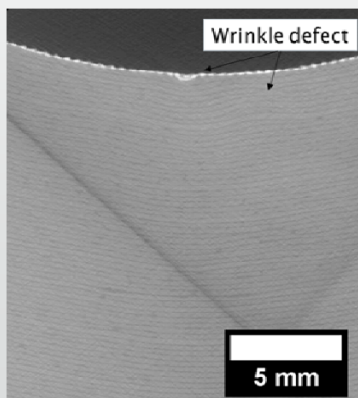
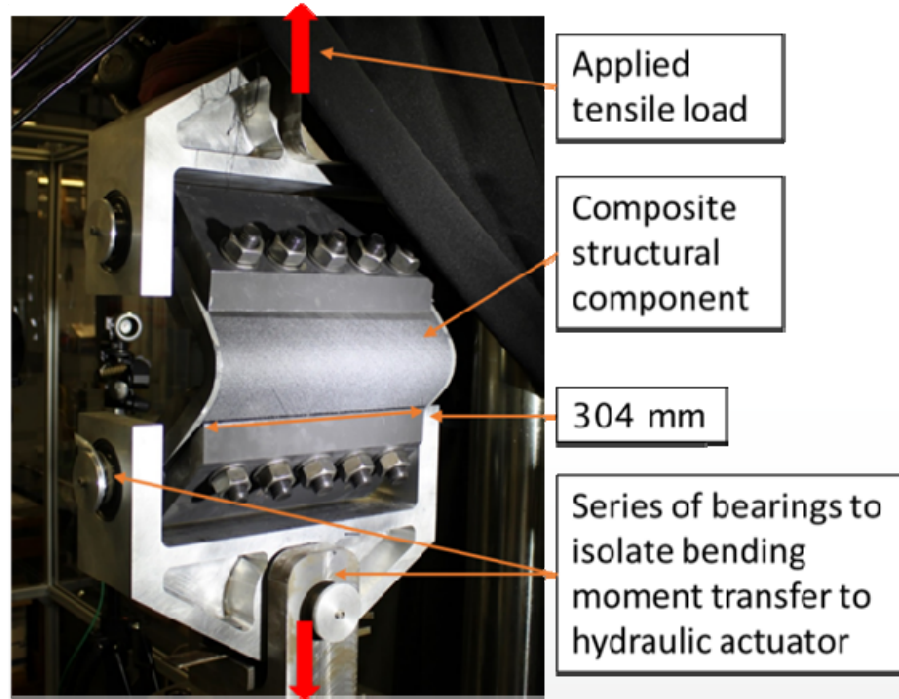
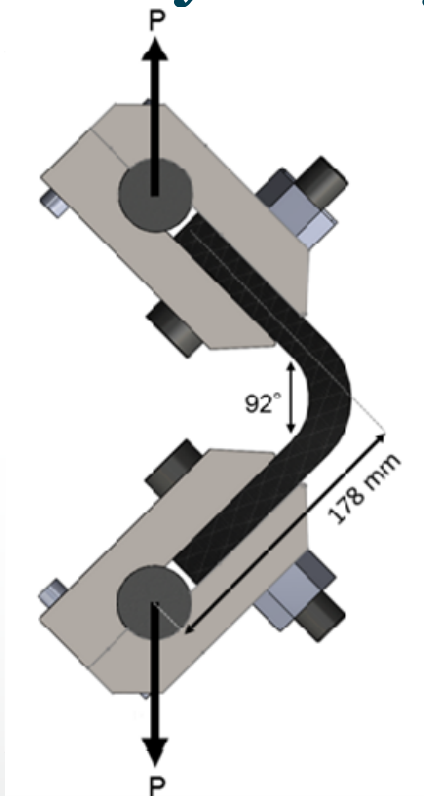
www.southampton.ac.uk/CompositeRegulations

Blackburn bus station
Courtesy of Millfield Composites Group
And Millfield Composites

‘Building block’ approach to certification

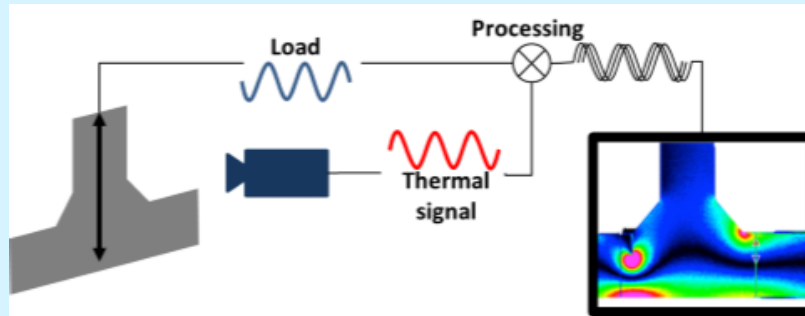


Feasibility study aircraft corner joint



Experimental technique

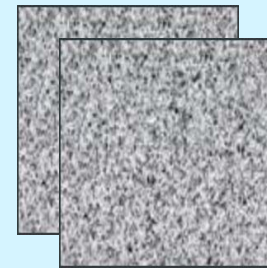
Thermoelastic stress analysis (TSA)



$$\Delta T = -\frac{T}{\rho C_p} (\alpha_1 \Delta \sigma_1 + \alpha_2 \Delta \sigma_2)$$

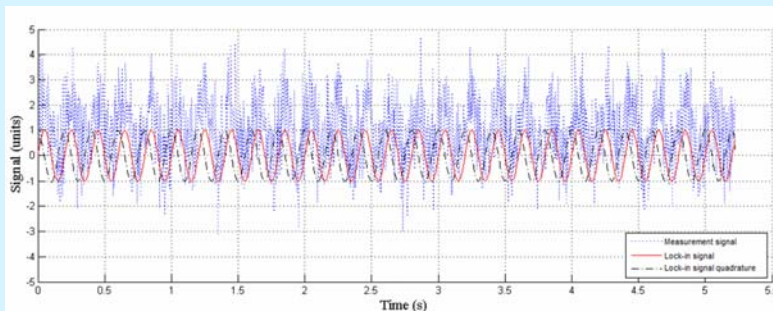
➡ Provides a stress metric

Digital Image Correlation (DIC)



Uses surface contrast to track displacements between two images to provide the component strains ϵ_x , ϵ_y and ϵ_{xy}

TSA uses lock-in processing to extract ΔT from a noisy signal

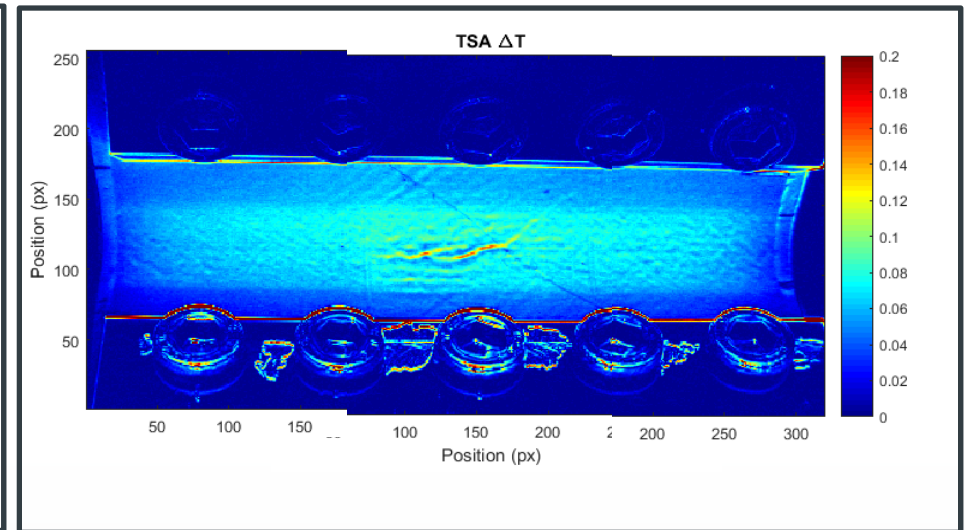
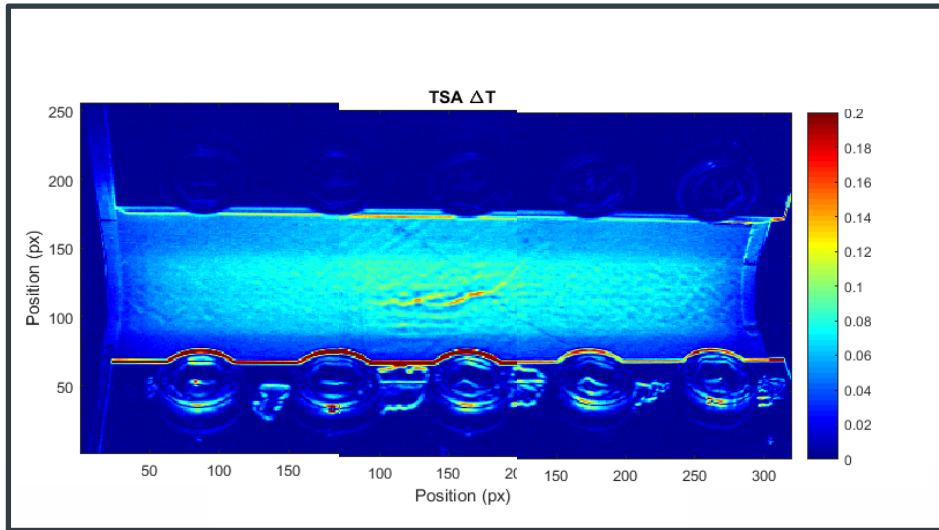


Lock-in DIC (LIDIC)

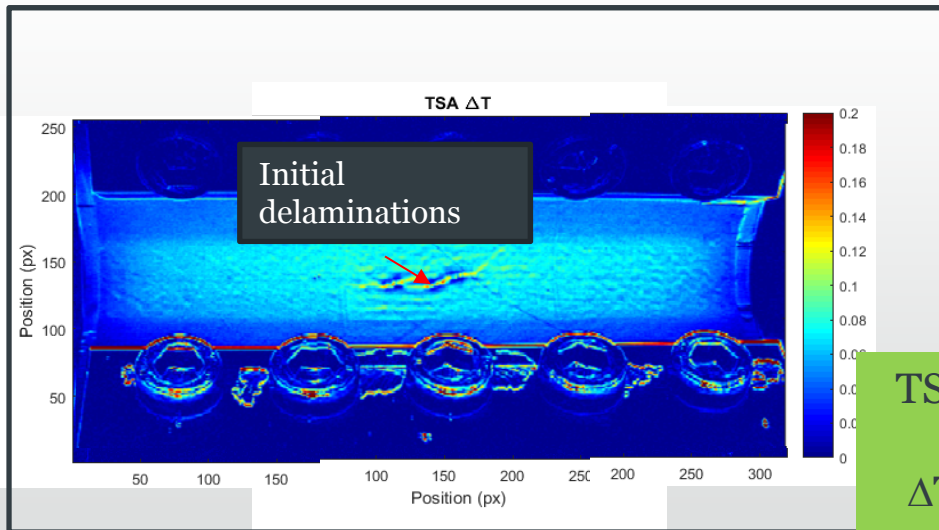
Uses lock-in processing to extract strains during cyclic loading so DIC and TSA are performed simultaneously to provide $\Delta \epsilon_x$, $\Delta \epsilon_y$ and $\Delta \epsilon_{xy}$ and ΔT

TSA: Inner corner after 1st, 2nd, 3rd and 4th load (delamination failure at 45 kN)

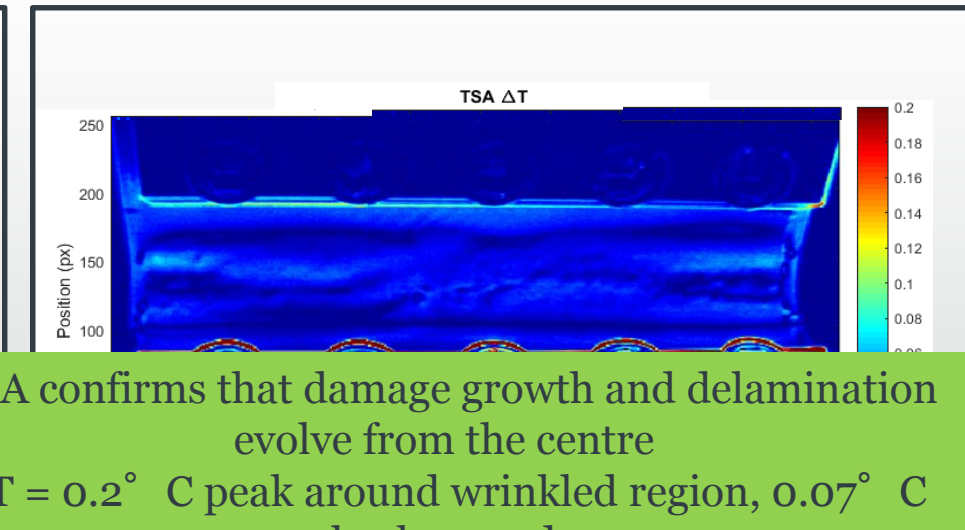
After 2nd load



After 3rd load

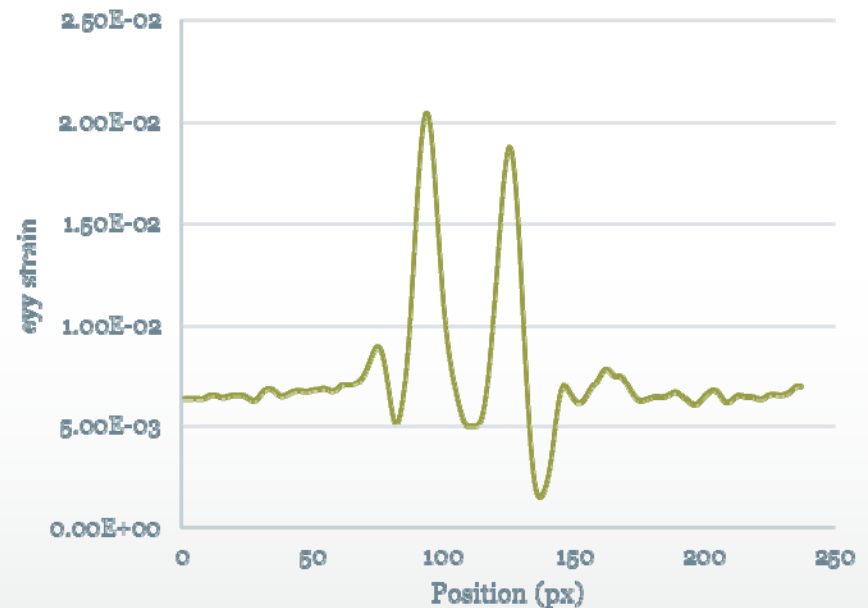
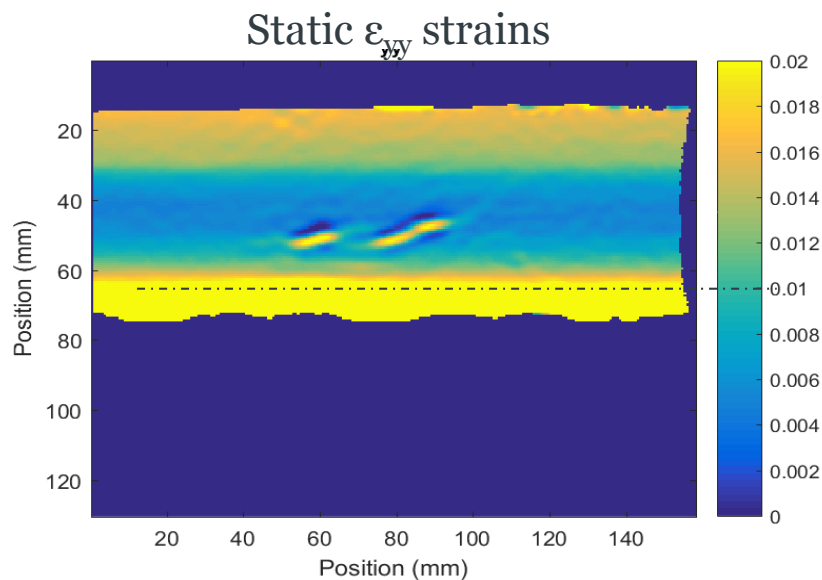


After 4th load



TSA confirms that damage growth and delamination evolve from the centre
 $\Delta T = 0.2^\circ \text{ C}$ peak around wrinkled region, 0.07° C background
 Stress concentration factor about 3

ϵ_{yy} immediately prior to load drop 44.1 kN



ϵ_{yy} strain 2.04% peak around wrinkled region, 0.67% background

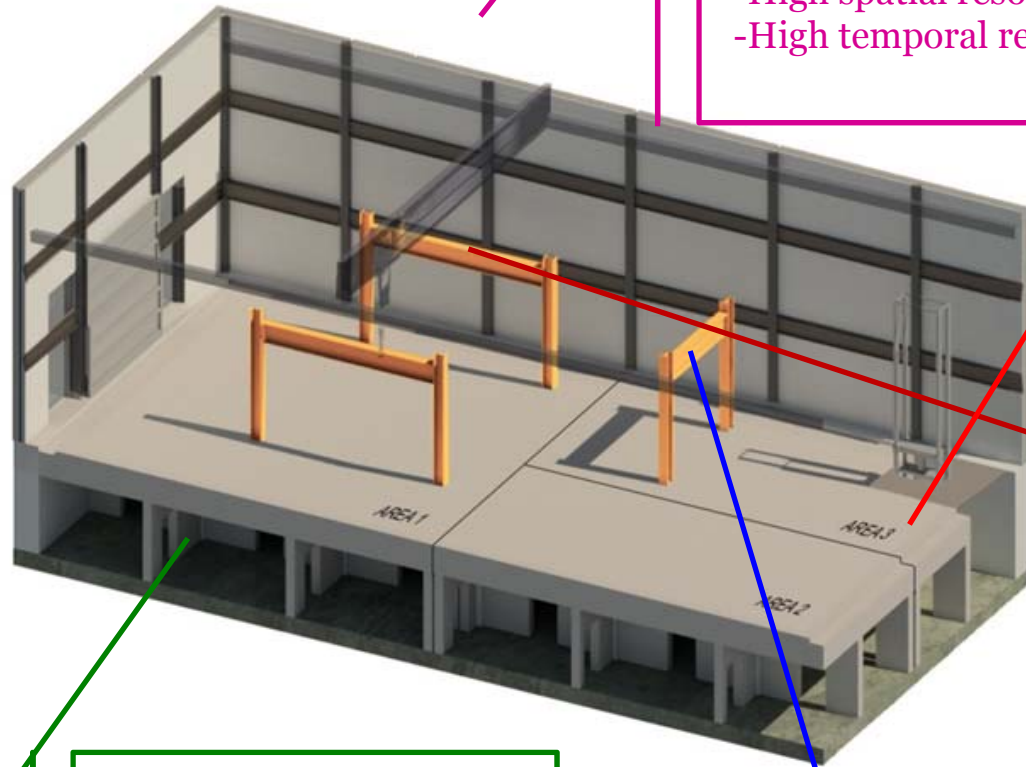
Strain concentration factor about 3

How far did we get – feasibility demonstrated?

- Composite substructure modelling and testing conducted successfully
- X-ray CT scan identified sub-surface wrinkle in spar corner
- TSA and LIDIC capture sub-surface wrinkle defects - local stress and strain fields & load redistribution during initiation and progression of delamination
- High-fidelity FE model accurately predicts onset of delamination failure – good correspondance between predicted (43 kN) and observed (44.1 kN) failure loads
- Next steps upscale.....

Structures 2025
Funded EPSRC -£1.2M
Industry £1M

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Imaging Systems

- Full-field data
- DIC
- TSA
- High spatial resolution
- High temporal resolution

Strong floor

- 1m thick reinforced concrete
- 30 x 15 m
- 1m spaced strong points
- 500 kN vertical 250 kN

Actuators:

- Large load range
- Synchronous control
- Flexibility

Hydraulics

- 1000 l/min ring main
- Large deflections
- High loads
- 'Plug and play'
- Complex loading

Load frames:

- Multi axial loading
- Flexible set up
- Large structures
- Modular design

EPSRC

Engineering and Physical Sciences
Research Council

Structures 2025

- A single integrated system
- Unique internationally
- Assessment of interactions between material failure mechanisms/modes and structural stiffness/strength driven failure modes
- Hitherto unattainable level of physical realism and fidelity

Industrial Sponsorship - £1M

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AIRBUS

ARUP



QinetiQ

