Structures 2025 Newsletter

February 2022

Vision

To provide a novel flexible integrated imaging and loading system for assessment of a wide range of structures across industry sectors following a major investment of £1.1M from EPSRC and matched funding from Industry.

Location

Structures 2025 (S2025) is housed in the Large Structures Testing Laboratory (LSTL) in the National Infrastructure Laboratory (N|I|L); which is part of the Boldrewood Innovation Campus at University of Southampton.

Key features of LSTL

- 30 m x 15 m strong floor.
- Hydraulic ring main system capable of delivering 1000 litres/min of hydraulic power at 280 bar.
- Purpose-built to enable advanced testing utilising data-rich imaging techniques over multiple length scales.
- Hybrid testing capability.

Structures 2025 Equipment and Achievements

- Actuators and control system have been supplied by MTS and commissioned in LSTL.
- The controller is an MTS FLEXTEST 200 which uses MTS AeroPro software, with facilities for hybrid testing.
- 5 actuators from MTS and 5 from Instron covering the range 100 to 2500 kN to allow multiple load paths to be developed.
- A reconfigurable set of fixtures and frames has been designed and manufactured to facilitate multiaxial loading of components as shown in Figures 1 and 2 (next pages).
- 2 x IX highspeed cameras, MatchID 4 camera optical metrology system, 4 x Infratec high resolution bolometer IR cameras.
- A substructural demonstrator based on a wind turbine section has been designed and currently being commissioned (next page), supported by Siemens Gamesa Renewable Energy.
- A demonstrator system has been designed and commissioned for hybrid testing with additional funding from Data and Analytics Facility for National Infrastructure (DAFNI) (3rd page).
- The facility is open for business and a guide to costs for using Structures 2025 is on the last page of the Newsletter.

Multi-axial testing of a wind turbine blade substructure

Wind Turbine Blades (WTBs) are large slender structures that are designed and certified by full scale modelling and testing using allowables from the coupon scale with appropriate knockdown factors. Substructure scale testing will allow more realistic allowables to be defined on the structural scale for global blade certification, as well as facilitating analysis of substructures using realistic design/operational load conditions.

WTB section demonstrator and load case design

- Specimen is a representative section of a WTB, where the shear web joins to the spar cap.
- Idealised to have a flat bottom and wider spar for easier manufacture, while containing identical laminate stacking sequences to WTB.
- Load cases defined by identifying key stress resultants from the global WTB FEA around the joint between the spar cap and web. and resolving closest matches with experimental constraints.

Test setup and data collection (Figure 1)

- 6 x 7 m footprint on the LSTL strong floor.
- Three independently controlled actuators apply cross-sectional and radial loads.
- Three regions of full-field imaging (combined TSA and DIC) at the specimen gauge zone.
- LVDTs placed around specimen to verify boundary conditions

Outlook and challenges

Resolving the complex global load state into achievable experimental conditions posed a significant challenge, therefore, key components were isolated instead. This test will provide new data regarding the structural behaviour of the T-joint under complex loading and provide a basis for future WTB substructure experiments.

Project sponsor

This project was setup in collaboration with Siemens Gamesa Renewable Energy.

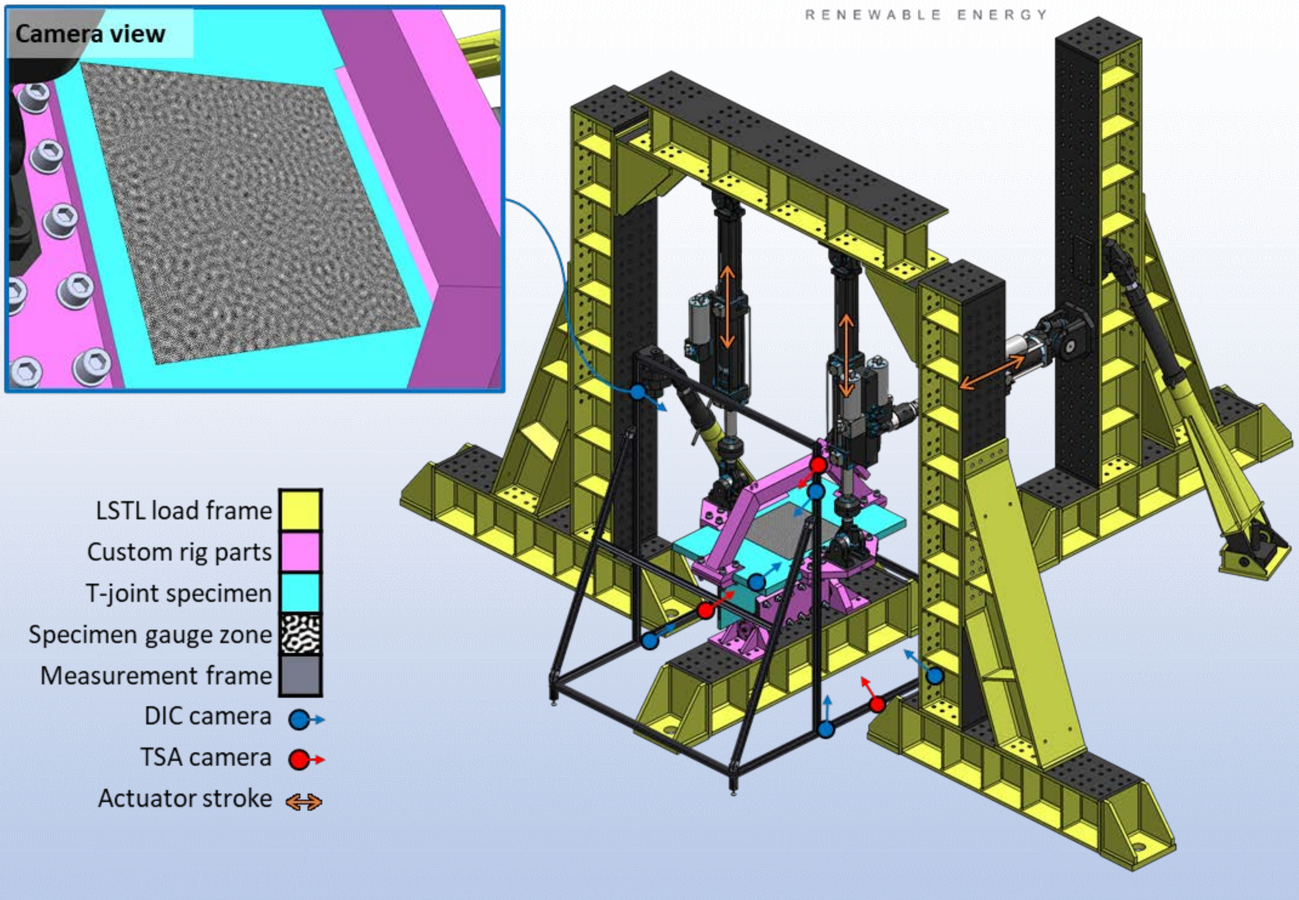


Figure 1. T-joint test setup and data collection

Hybrid testing – the future of substructure testing?

Hybrid testing is a combined experimental and numerical approach that allows physical testing of a subcomponent while the rest of the structure is simulated. For the validation of aerospace, transportation, or marine type structures, this opens new avenues of subcomponent testing at a fraction of the cost of full-scale tests, while capturing structural effects not present in coupon tests.

Hybrid testing demonstrator

- Structural assembly consisting of two cantilever steel plates connected by pin joints – Figure 2 (a)
- Link between model and experiment established through two actuators receiving displacement commands from the finite element (FE) software while feeding back the resulting force
- OpenFresco and MTSCSI used as middleware between FE and actuator controller software MTS AeroPro – Figure 2 (b)

Key commissioning test results

- Hybrid test load-displacement curves holistically match the FE reference solution obtained for the emulated (full) structural assembly – Figure 3
- Demonstrated that the subcomponent test is equivalent to the full-scale test
- Sensitivity study is ongoing to investigate the effects of model and experimental parameters on the hybrid testing results

Outlook and challenges

The application of hybrid testing to more complex subcomponent, such as shown in Figure 1 (previous page), poses significant challenges due to their 'continuous' nature, where sub structuring leads to complex shared boundaries between the experimental and numerical components. This necessitates the need for advanced experimental methods to control and monitor the test. It is the aim of Structures 2025 to develop the required capabilities, and to integrate full-field imaging techniques such as digital image correlation (DIC) and thermoelastic stress analysis (TSA).

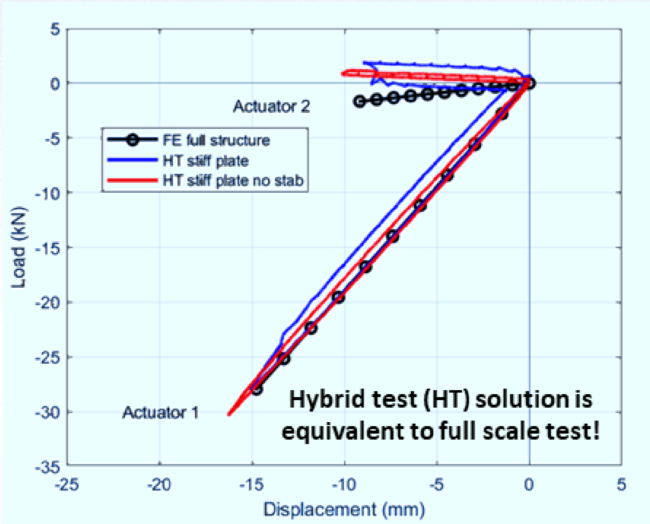
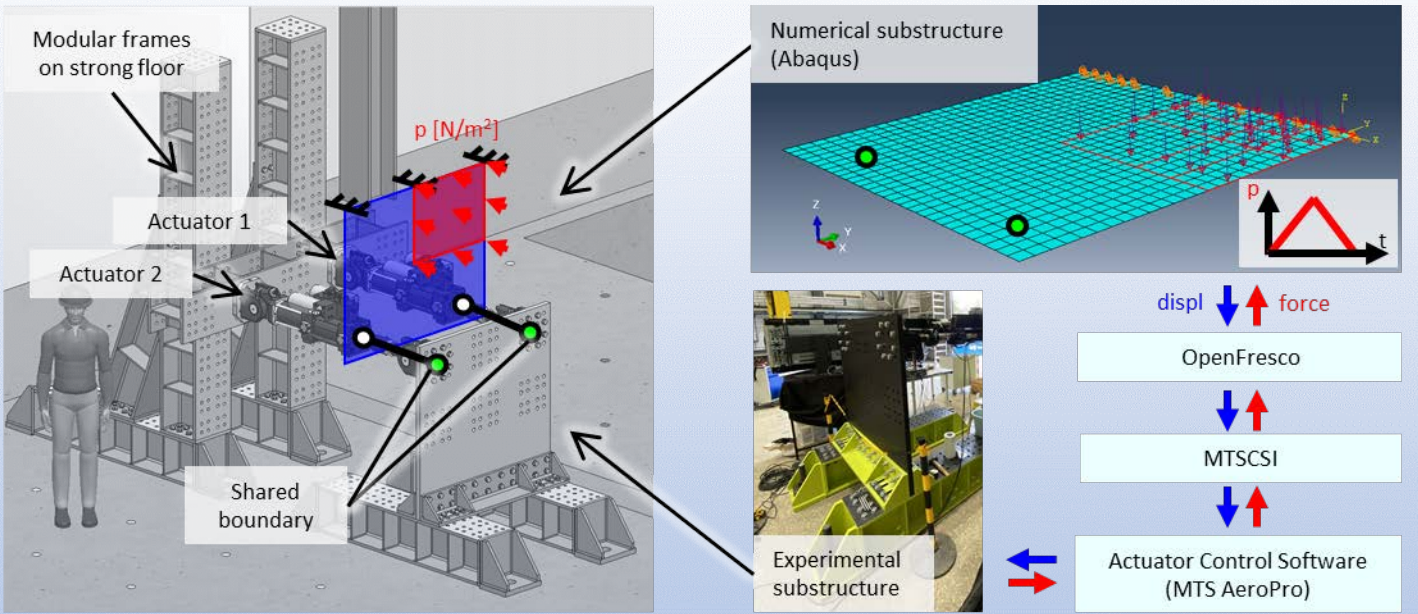


Figure 3. Load-displacement curves obtained from the hybrid testing in comparison to the FE reference solution of the 'emulated' structural assembly.



(a) (b)

Figure 2. Hybrid testing set-up: (a) emulated structural assembly and (b) command control loop.

Accessing the S2025 and other testing facilities at LSTL

The Large Structures Testing Laboratory (LSTL) is a facility for testing structures, components, and materials at a range of scales. It is a state-of-the-art testing facility for data-rich structural testing, using multi-axis actuation and advanced image analysis techniques to detect system behaviour. The facility is used for research, teaching and commercial applications (www.southampton.ac.uk/engineering/research/facilities/large-structures.page). A full capability document is available on request.

Project funding

Projects can be funded in three main ways:

- Consultancy – Projects are completed by experienced experimental staff @ £750-1000 per day (plus facility costs)
- Funding studentships – KTP, studentship a contribution to facility costs and £12k per annum for studentship
- Direct access – For experienced experimentalists from other institutions projects can be conducted with direct access (facility costs only)

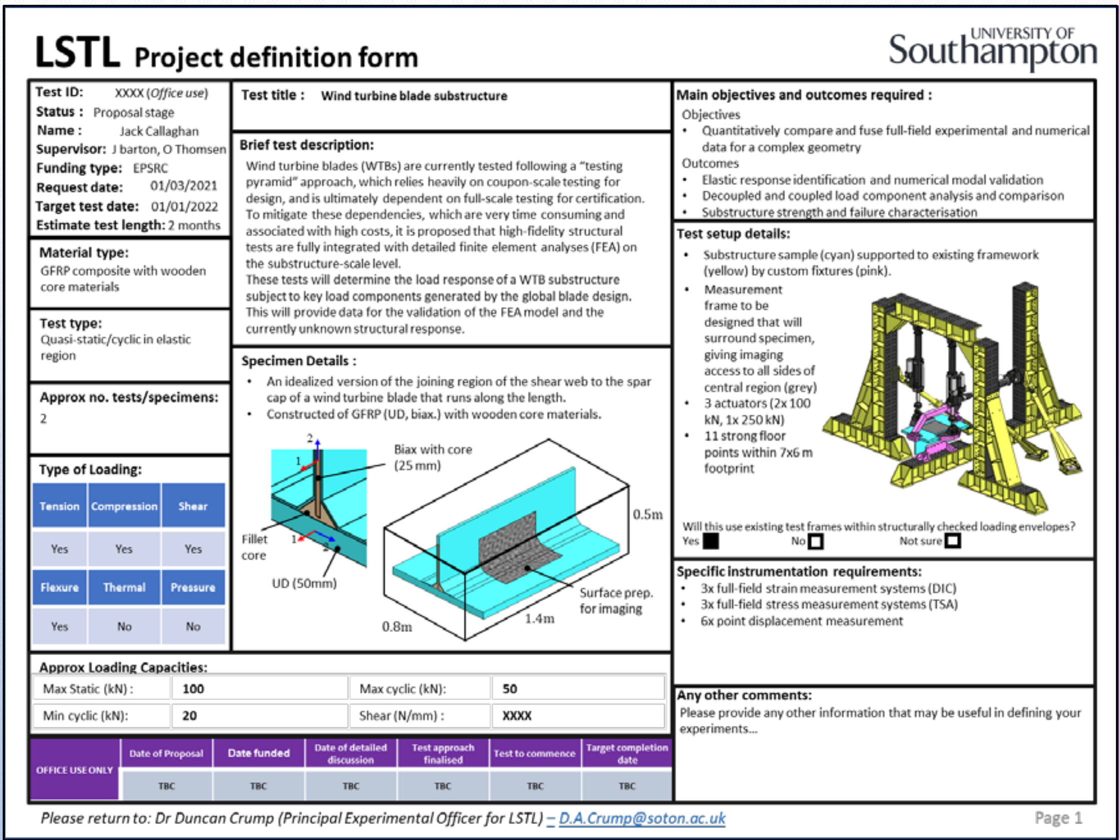
Facility costs

Facility costs for LSTL are split into a number of per day charge rates:

Actuators and control systems:	£122	Instrumentation:	£138
Strong floor space/support (per m^2):	£1.15	Reaction frames:	£124
Optical measurement systems:	£130-300	Hydraulic system:	£108
Consultancy (dependent on experience):	£750-1000		

Getting started

The starting point to any project is a project definition form (an example for the wind turbine demonstrator is included below). This should be emailed to Dr Duncan Crump d.a.crump@soton.ac.uk. As an example, the facility costs for the demonstrator project were £25,989.



LSTL Project definition form

UNIVERSITY OF Southampton

Test ID: XXXX (*Office use*)
Status : Proposal stage
Name : Jack Callaghan
Supervisor: J barton, O Thomsen
Funding type: EPSRC
Request date: 01/03/2021
Target test date: 01/01/2022
Estimate test length: 2 months

Material type:
GFRP composite with wooden core materials

Test type:
Quasi-static/cyclic in elastic region

Approx no. tests/specimens:
2

Type of Loading:

Tension	Compression	Shear
Yes	Yes	Yes
Flexure	**Thermal**	**Pressure**
Yes	No	No

Test title : Wind turbine blade substructure

Brief test description:
Wind turbine blades (WTBs) are currently tested following a "testing pyramid" approach, which relies heavily on coupon-scale testing for design, and is ultimately dependent on full-scale testing for certification. To mitigate these dependencies, which are very time consuming and associated with high costs, it is proposed that high-fidelity structural tests are fully integrated with detailed finite element analyses (FEA) on the substructure-scale level.
These tests will determine the load response of a WTB substructure subject to key load components generated by the global blade design. This will provide data for the validation of the FEA model and the currently unknown structural response.

Specimen Details :
- An idealized version of the joining region of the shear web to the spar cap of a wind turbine blade that runs along the length.
- Constructed of GFRP (UD, biax.) with wooden core materials.

Main objectives and outcomes required :
Objectives
- Quantitatively compare and fuse full-field experimental and numerical data for a complex geometry

Outcomes
- Elastic response identification and numerical modal validation
- Decoupled and coupled load component analysis and comparison
- Substructure strength and failure characterisation

Test setup details:
- Substructure sample (cyan) supported to existing framework (yellow) by custom fixtures (pink).
- Measurement frame to be designed that will surround specimen, giving imaging access to all sides of central region (grey)
- 3 actuators (2x 100 kN, 1x 250 kN)
- 11 strong floor points within 7x6 m footprint

Will this use existing test frames within structurally checked loading envelopes?
Yes ■ No □ Not sure □

Specific instrumentation requirements:
- 3x full-field strain measurement systems (DIC)
- 3x full-field stress measurement systems (TSA)
- 6x point displacement measurement

Approx Loading Capacities:

Max Static (kN) :	100	Max cyclic (kN):	50
Min cyclic (kN):	20	Shear (N/mm) :	XXXX

Any other comments:
Please provide any other information that may be useful in defining your experiments...

OFFICE USE ONLY	Date of Proposal	Date funded	Date of detailed discussion	Test approach finalised	Test to commence	Target completion date
	TBC	TBC	TBC	TBC	TBC	TBC

Please return to: Dr Duncan Crump (Principal Experimental Officer for LSTL) – D.A.Crump@soton.ac.uk

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