Applus+ DatapointLabs

Testing and validation of adhesive materials

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TestCart

TestPaks

CAETestBench

EST 1995
ISO 17025 Quality

OpenRadioss™

Applus+, DatapointLabs & Materials Characterization

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Applus+ Group

Applus+ is a global leader in inspection, testing and certification. Driven by our passion for progress and technological development, we'll keep moving towards a more sustainable future alongside our customers; re-enforcing our mission and company motto: **Together beyond standards.**

26,000+
People

€ 2,058M
Revenue

65+
Countries in all continents

Accredited
By main international entities

Energy & Industry Division

€ 1,084M revenue

16,000+ personnel

Laboratories Division

€ 264M revenue

2,589 personnel

Automotive Division

€ 392M revenue

4,300 personnel

IDIADA Division

€ 331M revenue

3,158 personnel

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ITHACA, NY
USA

OVERVIEW OF DATAPOINTLABS

Experience

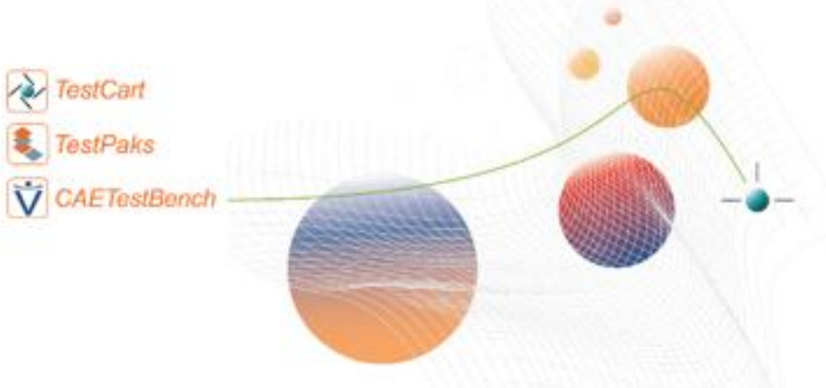
- +30 years of experience in materials testing and characterization
  - ISO 17025:2017 accredited, operating on an end-end digital platform
  - Nadcap accredited [Aerospace / Defense] (Metallic/Non-Metallic Materials Testing)

Operations

- Testing 2000+ materials per year
- Standard 5-day turnaround
- Comprehensive one-stop testing capability
  - +200 unique tests: all aspects of mechanical, thermal and rheological characterization

Capabilities

- Materials: plastics, composites, foam, rubber, metals, additive materials, films, adhesives
- May be characterized over a wide range of temperature and environmental conditions (elevated/cryogenic, heat aging, moisture conditioning, weathering, fluid exposure, in-vivo)
- Characterize non-linear and post-yield behavior, dynamic situations (drop, crash, impact), hyperelasticity (rubber, foams), time-based behavior (creep, stress relaxation, viscoelasticity)



Nadcap
Administered by PRI
ACCREDITED
Certificate# 17231205927
Non Metallic Materials Testing

ISO
ISO 17025

https://www.datapointlabs.com/

Why adhesive modelling is difficult?

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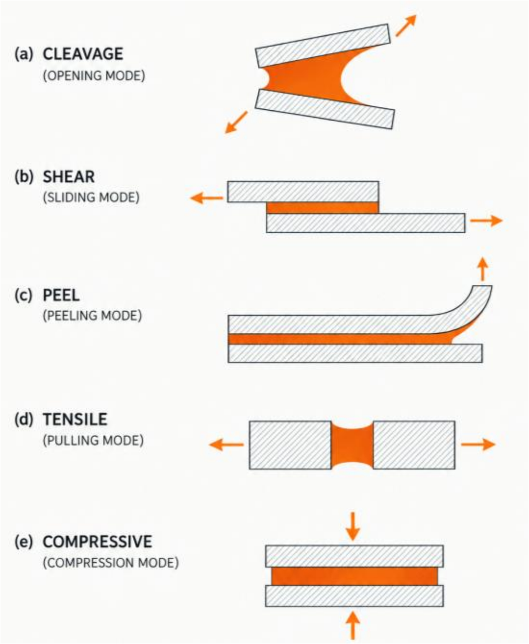
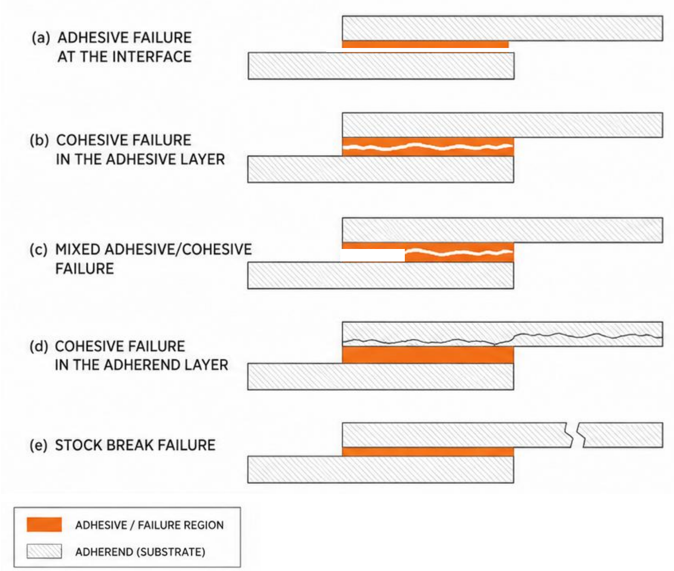
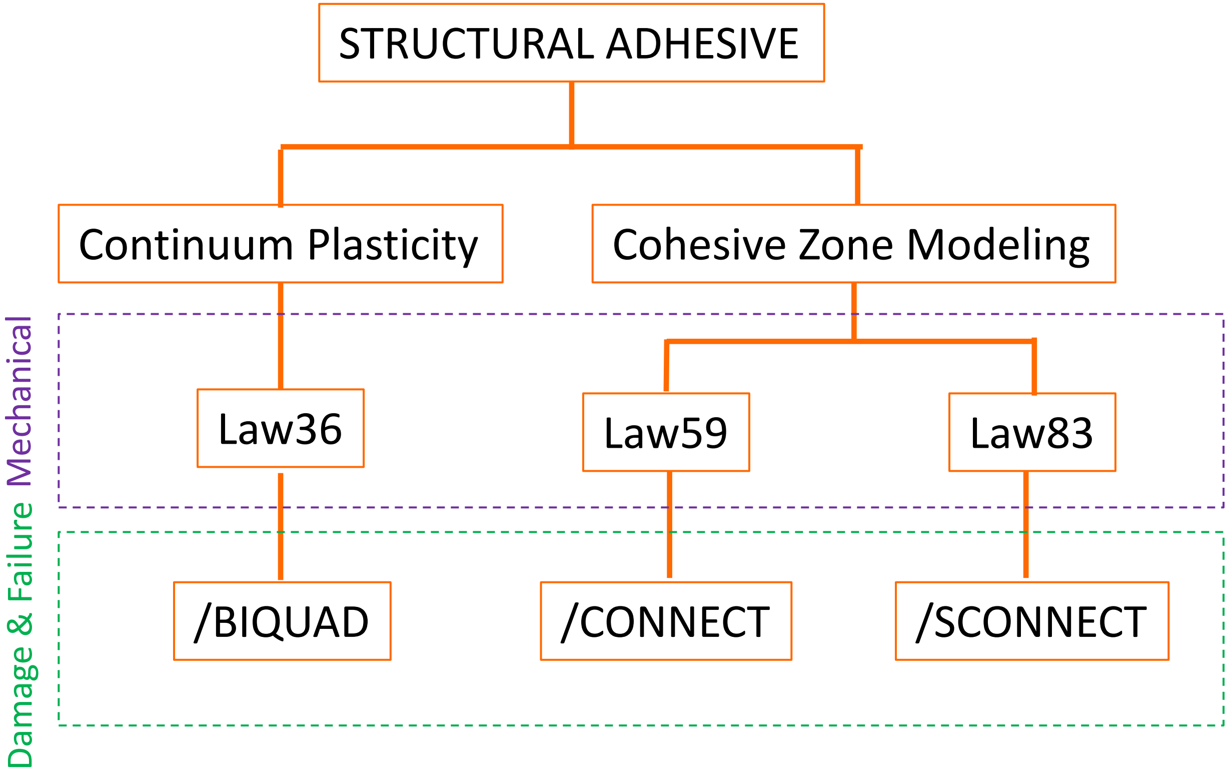
Types of Joint Stress



Type of failures



Some models available



Hypothesis and Objectives

Hypothesis

Can different Radioss material formulations be calibrated to the same experimental adhesive response—and, if so, do they remain equivalent when applied to structural loading?

Objectives

1. Calibration: Obtain equivalent representations of the same epoxy
2. Verification: Compare tensile and shear simulations against experiments
3. Structural validation: Test peeling and T-frame behavior
4. Model-selection: Understand when each formulation is appropriate

Equivalent calibration ≠ equivalent structural prediction

Three models, three philosophies

	LAW 36	LAW 59 + CONNECT	LAW 83 + SCONNECT
Representation	Bulk continuum	Cohesive	Cohesive
Main behavior	Plasticity/damage	Normal + tangential	Coupled normal + tangential
Thickness	Physical	Adhesive thickness	Adhesive thickness
Normal Response	Stress-strain	Traction-separation	Traction-separation
Shear Response	Bulk shear	Tangential cohesive	Coupled cohesive
Mixed Mode	Indirect	Failure interaction	Explicit coupling
Calibration effort	Low	Moderate	Moderate
Physical interpretation	Bulk adhesive	Interface/cohesive	Interface/cohesive

LAW36: Elasto-plastic tabular model

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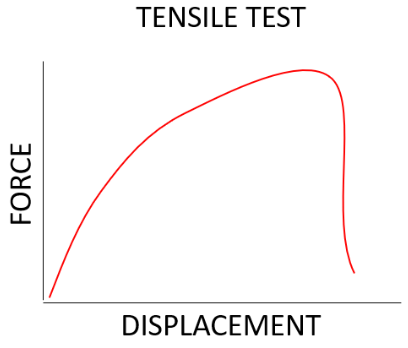
Formulation

$$\sigma = f(\epsilon, \epsilon p)$$

$$\sigma = E\epsilon \qquad \sigma = f(\epsilon p)$$

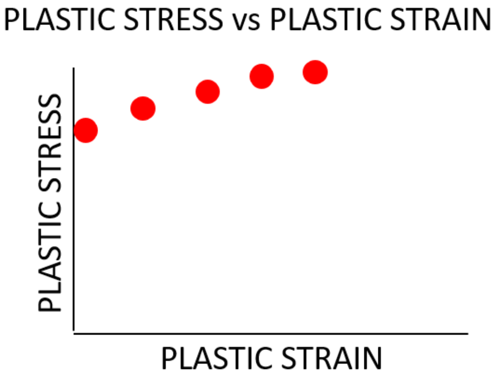
$$D = D(\epsilon, \dots)$$

Calibration



Elastic Parameters

- Density
- Elastic Modulus
- Poisson Ratio
- Failure Strain



Advantages

- Straightforward bulk response (incl. Strain Rate dependency)
- Good for large deformation/plasticity
- Natural continuum representation

Disadvantages

- Adhesive fracture is not intrinsically described as a traction–separation process
- Real thickness must be modelled with solid elements

LAW59 + Connect

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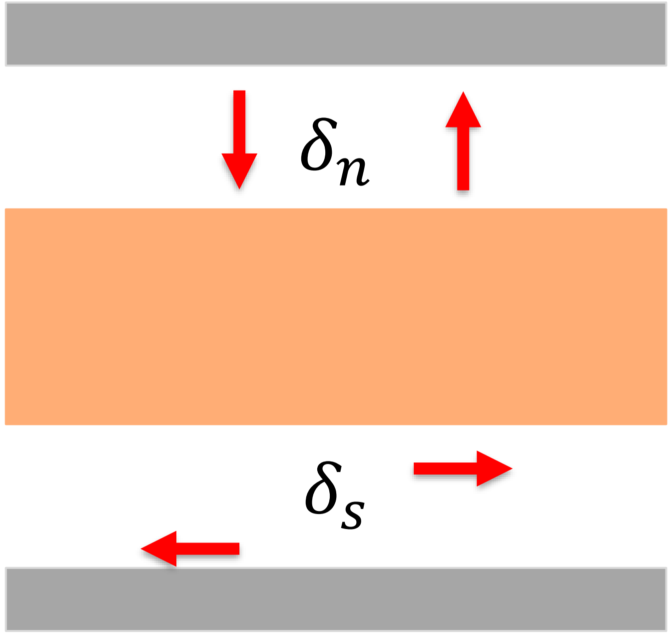
Concept



Formulation

$$T_n = f(\delta_n)$$

$$T_s = f(\delta_s)$$

+

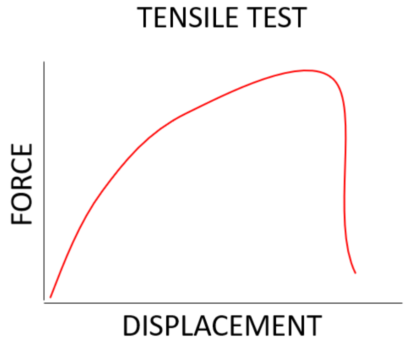
$$G_I = \int T_n d\delta_n$$

$$G_{II} = \int T_s d\delta_s$$

+

$$F(T_n, T_s) = 1$$

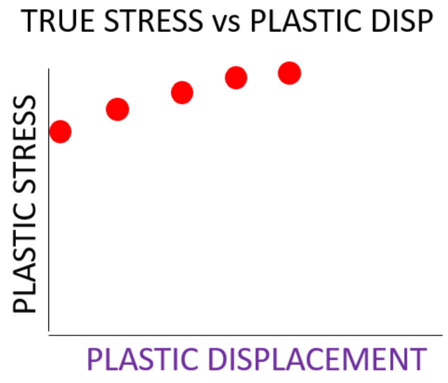
Calibration



- NORMAL
- TANGENT

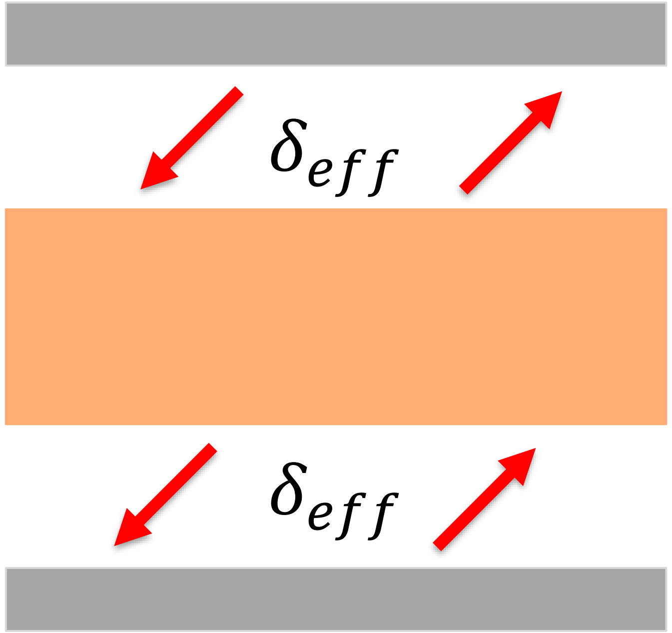
Elastic Parameters

- Density
- Elastic Modulus
- Max. Stresses
- Fracture Energy/displ.



LAW83 + SConnect

Concept



Normal and shear plasticity are coupled in a single mixed-mode formulation

Formulation

$$T_{eff} = f(T_n, T_s)$$

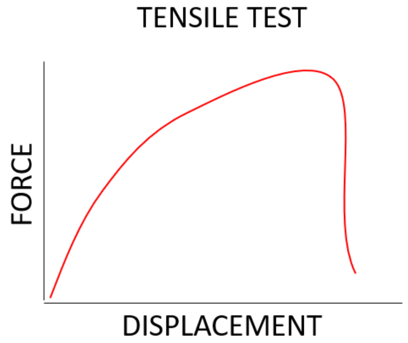
$$\sigma_y^{eff} = [\left(\frac{\sigma_n}{R_N f_N(1-\alpha_{sym})}\right)^{\beta} + \left(\frac{\sigma_s}{(R_S f_S)}\right)^{\frac{1}{\beta}}]$$

$u_{f,n}^{pl}, u_{f,s}^{pl} \rightarrow failure$

$\beta_0, \beta_f \rightarrow mixed\text{-}mode\ failure$

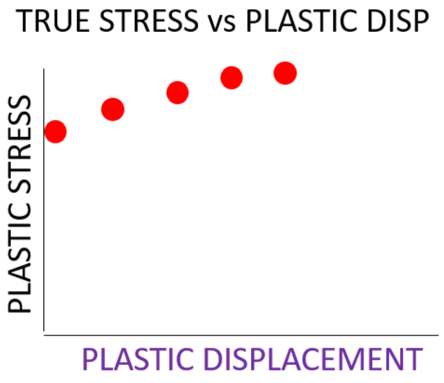
$\alpha_0, \alpha_f \rightarrow moment/peel\ effect$

Calibration



Elastic Parameters

- Density
- Elastic Modulus
- Max. Stresses
- Fracture Energy/displ.



What do we need to characterize?

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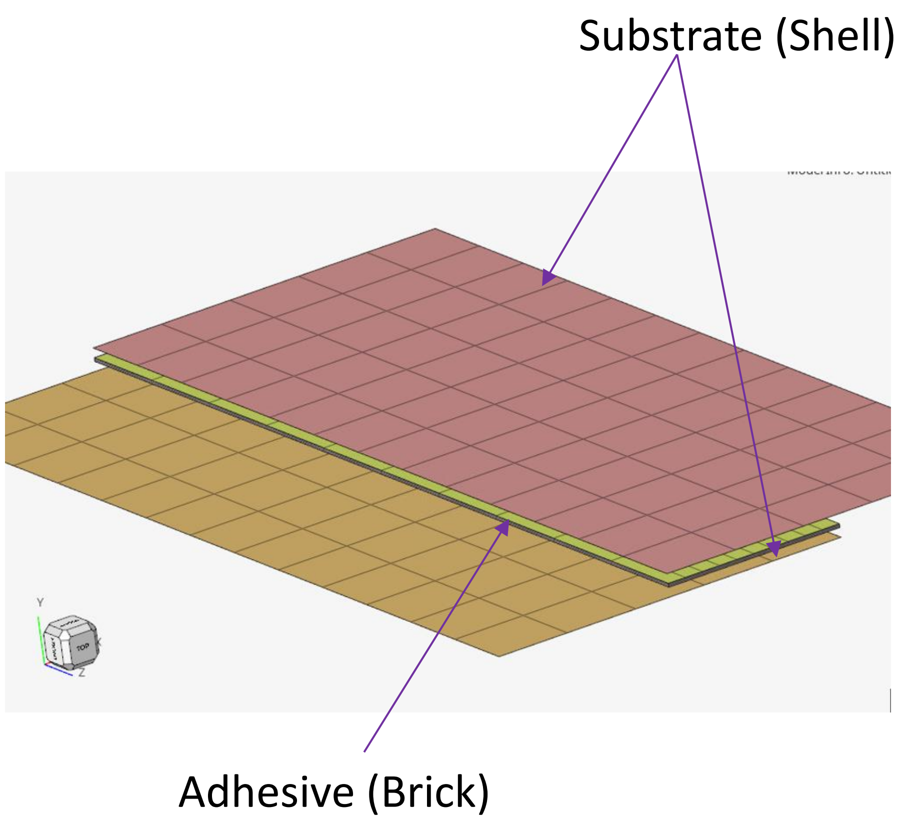
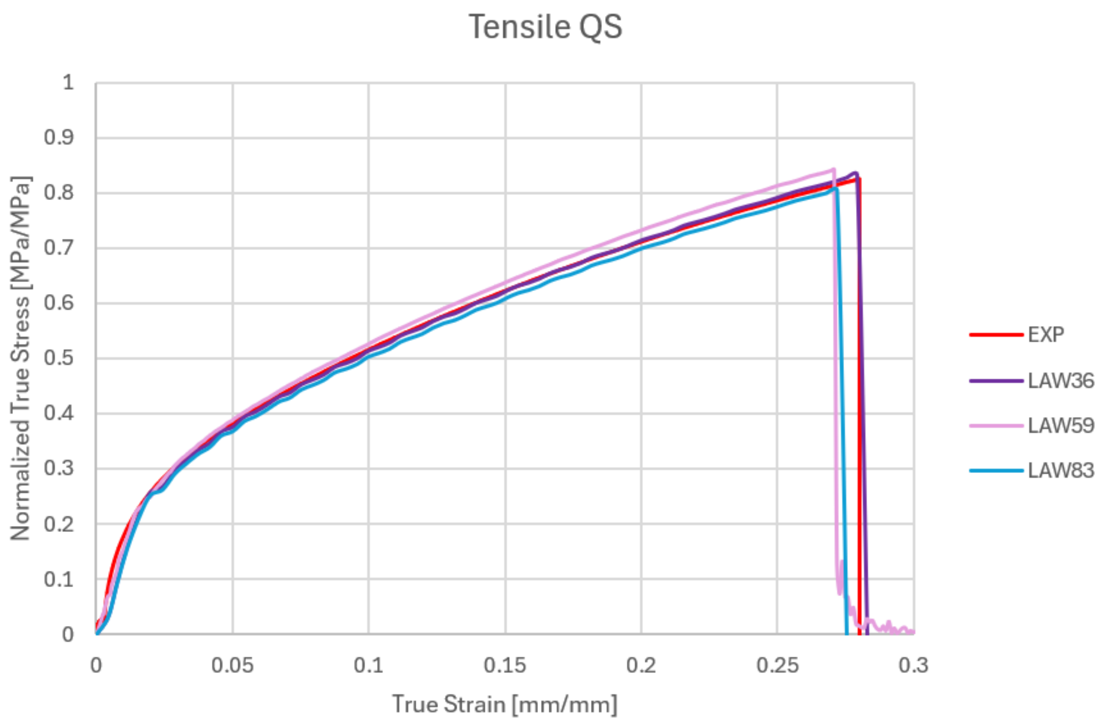
Test Name	Standard	Material Parameters	Model
Bulk Tensile Test	ISO 527-2	Young Modulus Poisson’s Ratio Hardening Curves	Law36 / Law59 / Law83
Thick Adherent Shear Test	ISO 11003-2	Shear strength Tangential Hardening Curves	Law59 / Law ¡83
Mode I Fracture Toughness	EN 6033	Mode I Fracture Energy	Law59 / Law83
Mode II Fracture Toughness	EN 6033	Mode II Fracture Energy	Law59 / Law83
T-Frame	Simulation	Comparison	Law36 / Law59 / Law83

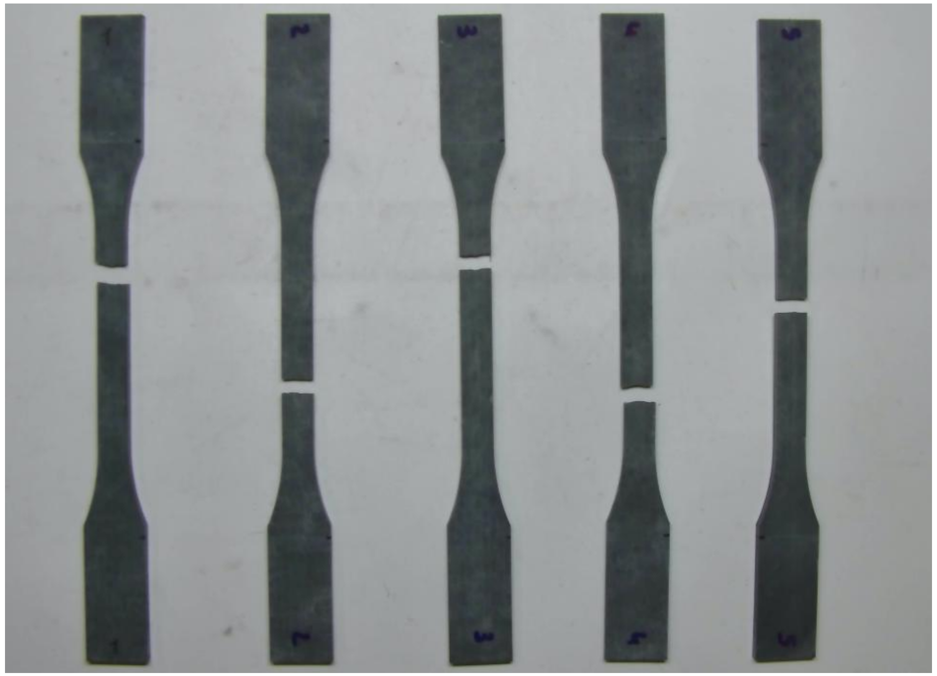
Numerical Modeling Approach

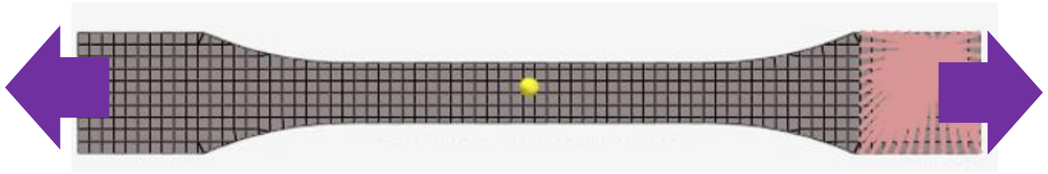
- Finite Element simulations performed using the Radioss explicit solver
- Adhesive layers modeled with 3D solid elements (8 node hexahedral elements TYPE43)
- Metallic substrate modeled with shell elements to reduce computational cost
- Mesh refinement applied in the adhesive layer2–3 elements through the adhesive thickness
- Coarser mesh in substrates
- Adhesive behavior described using:
  - LAW36
  - LAW59 + CONNECT
  - LAW83 + SCONNECT
- TIED Contact between adhesive and substrates
- Displacement-controlled loading used in all simulations
- Quasi-static conditions ensured by low loading rates and energy balance checks



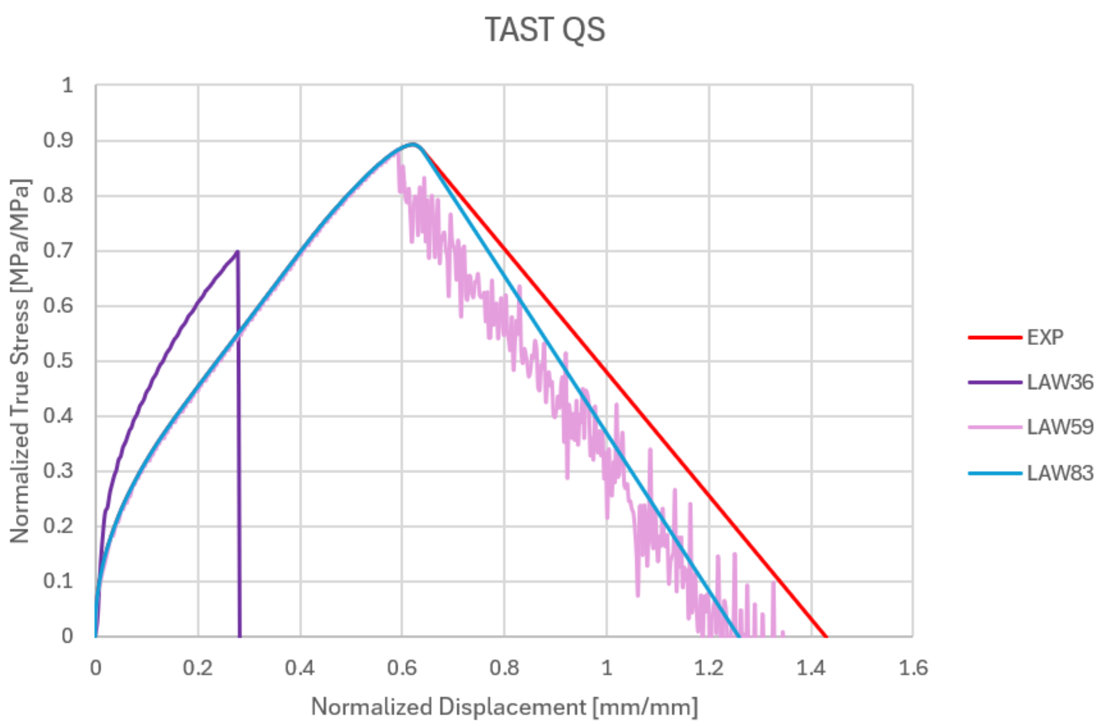
Results: Tensile validation

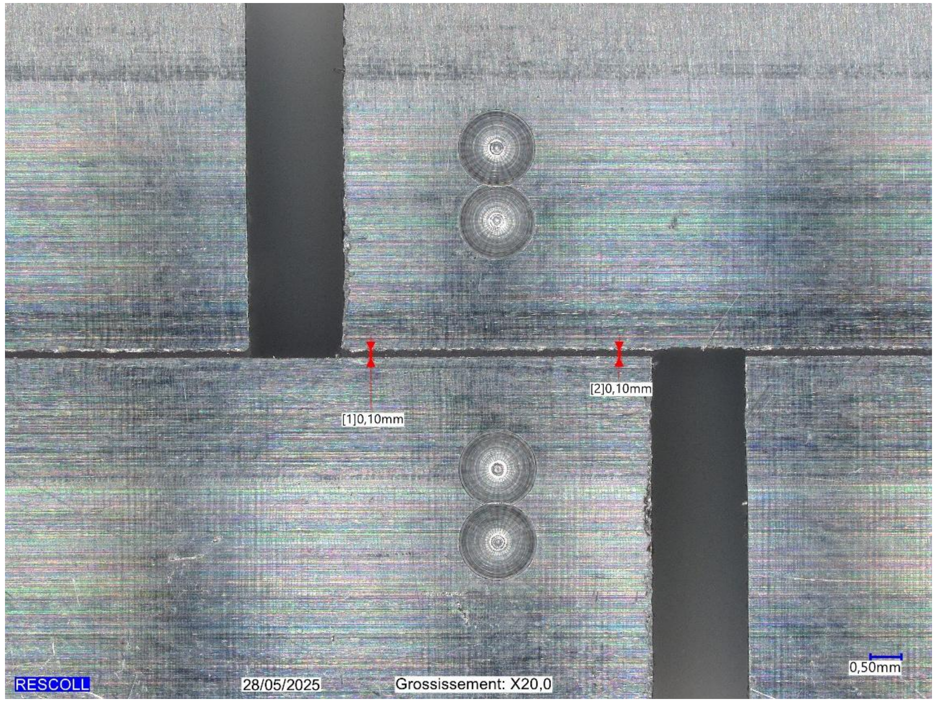


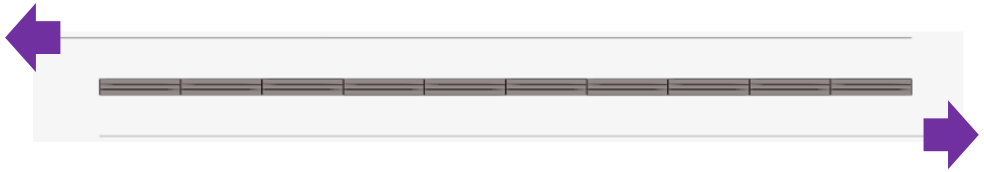




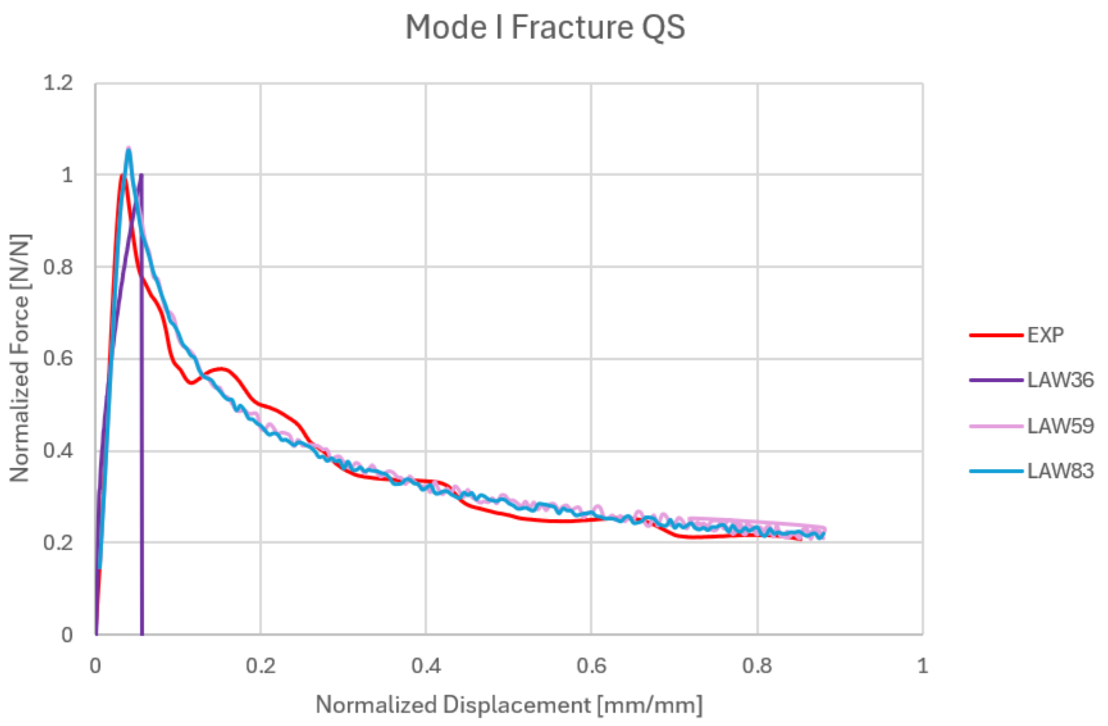
Results: Shear validation

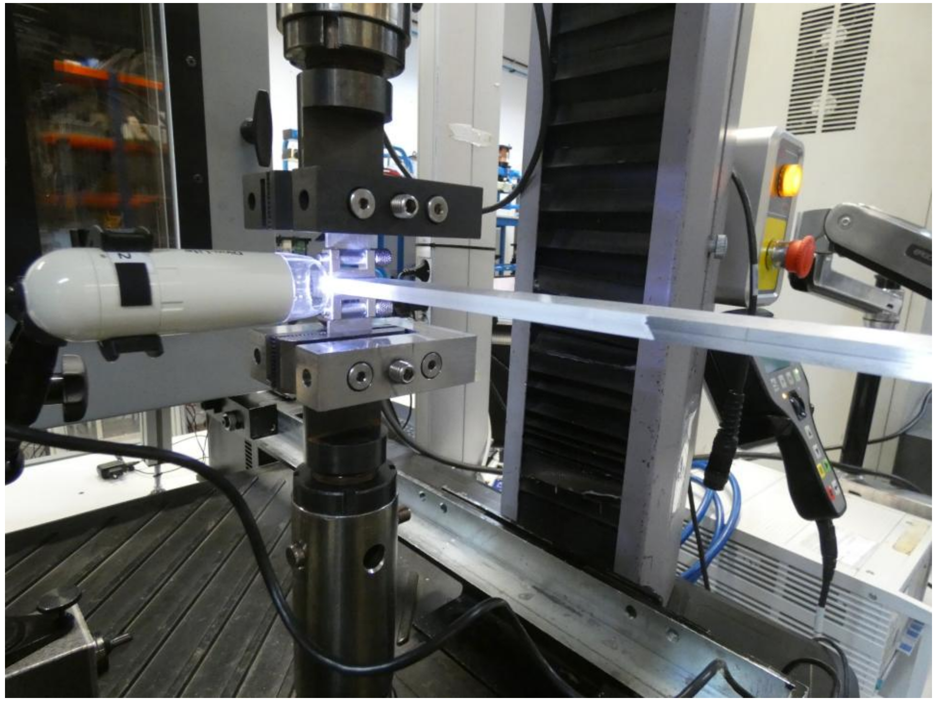


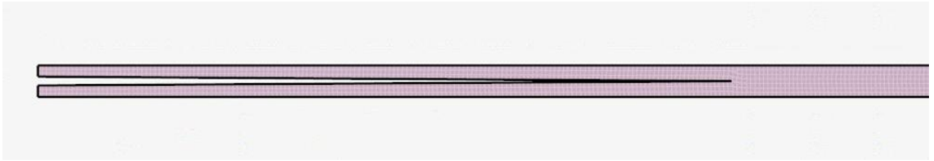




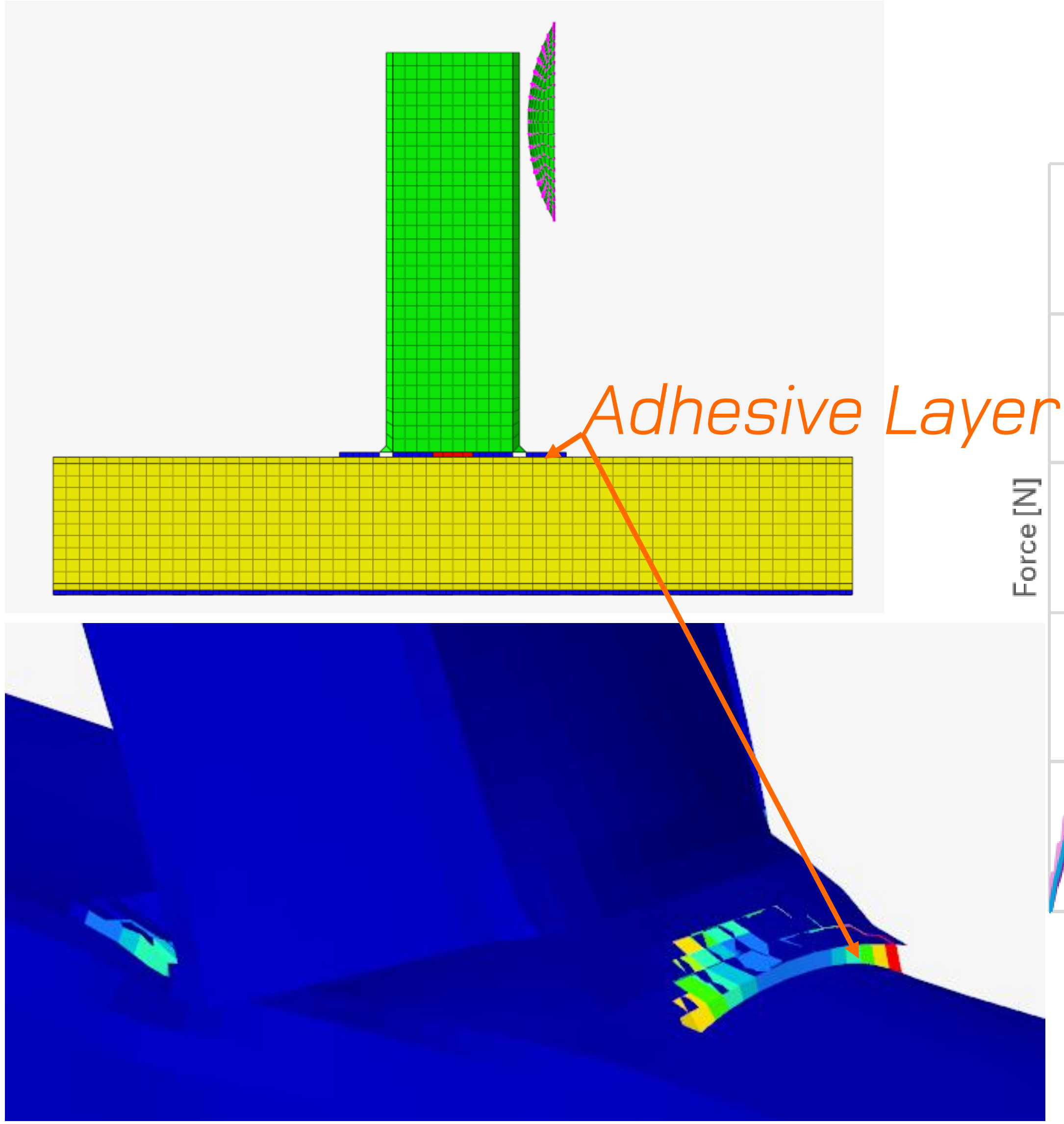
Results: Ply peeling / Mode-I

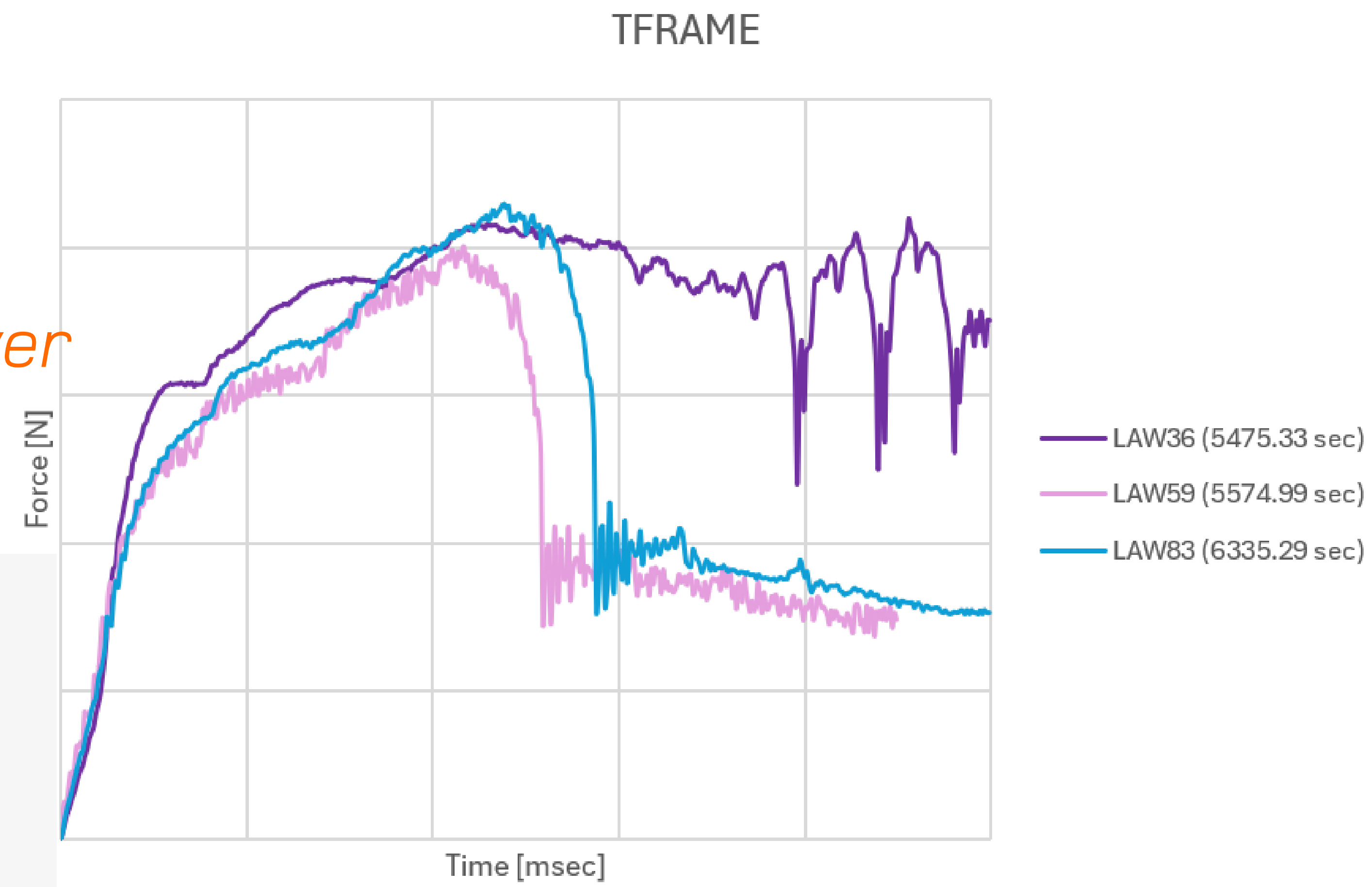






Results: T-frame





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Model courtesy of Marian Bula (Open Radioss)

Global comparison

Test Name	LAW36	LAW59 + CONNECT	LAW83 + SCONNECT
Bulk Tensile Test	Robust	Robust	Robust
Thick Adherent Shear Test	Acceptable	Robust	Robust
Mode I Fracture Toughness	Limited	Robust	Robust
T-Frame			
Calibration Complexity	Low	Moderate	Moderate
Computational Cost	Low	Moderate	Moderate
Physical Fracture Representation	Low	Accurate	Accurate

Conclusions

1. Calibration:
   All three formulations can be calibrated to reproduce selected experimental responses
2. Model formulation Matters:
   Similar coupon-level behavior does not guarantee equivalent structural predictions
3. Cohesive models:
   LAW59 and LAW83 provide a more explicit representation of adhesive separation and fracture than a bulk LAW36 formulation
4. Testing matters:
   The quality of the numerical prediction is fundamentally limited by the quality of the experimental characterization

Thank You!

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