

Material Characterization with Representative Volume Simulations of Woven Polymer Matrix Composites

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Goals and Summary

Goals & Approach:

- Implement constitutive models for composite simulations
- Provide a verified and validated toolset for composite property predictions using representative volume elements (RVE)

Summary:

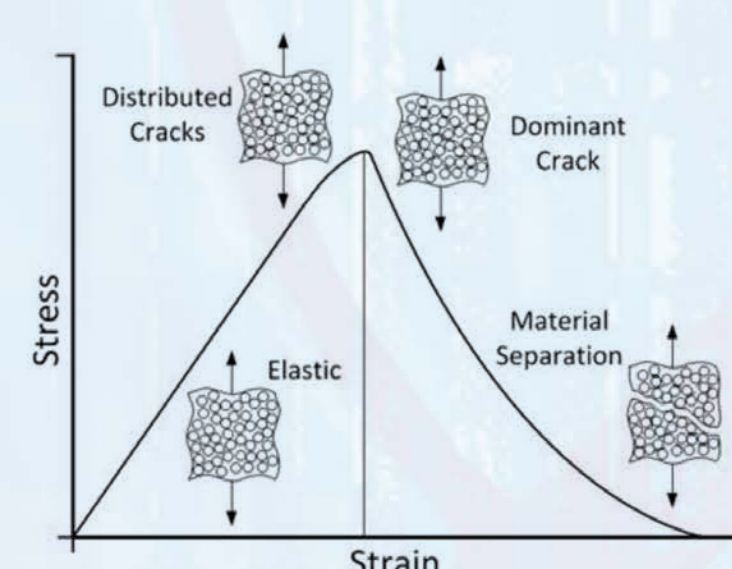
Key R&D Accomplishments

- Constitutive model evaluations and implementation for composite simulations
- Comprehensive methodology and toolset for validated elastic and damage property predictions of unidirectional and woven composites

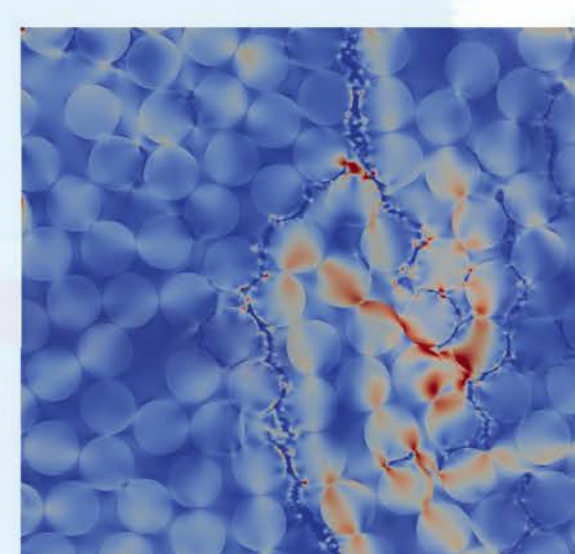
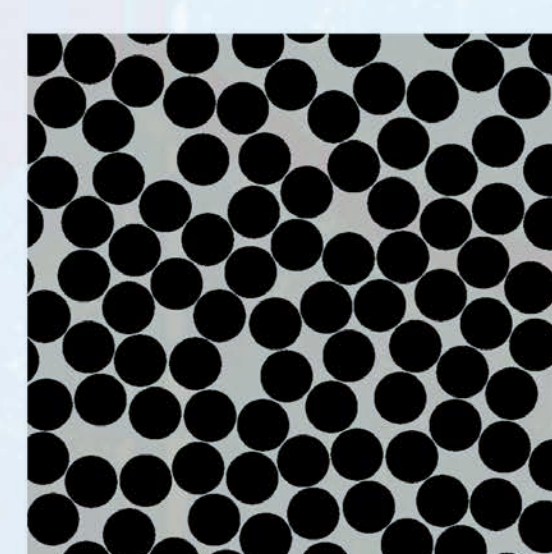
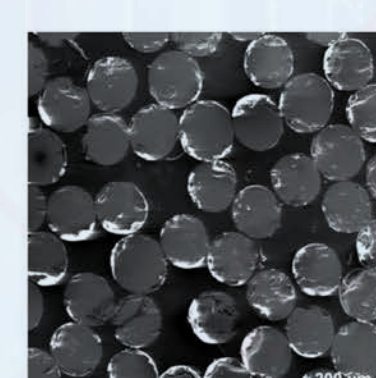
Significance of Results

- Elastic property predictions for a wide range of composite materials with minimal experimental efforts
- Potential for complex damage/failure predictions
- Constitutive models currently in use

Micromechanical Simulations

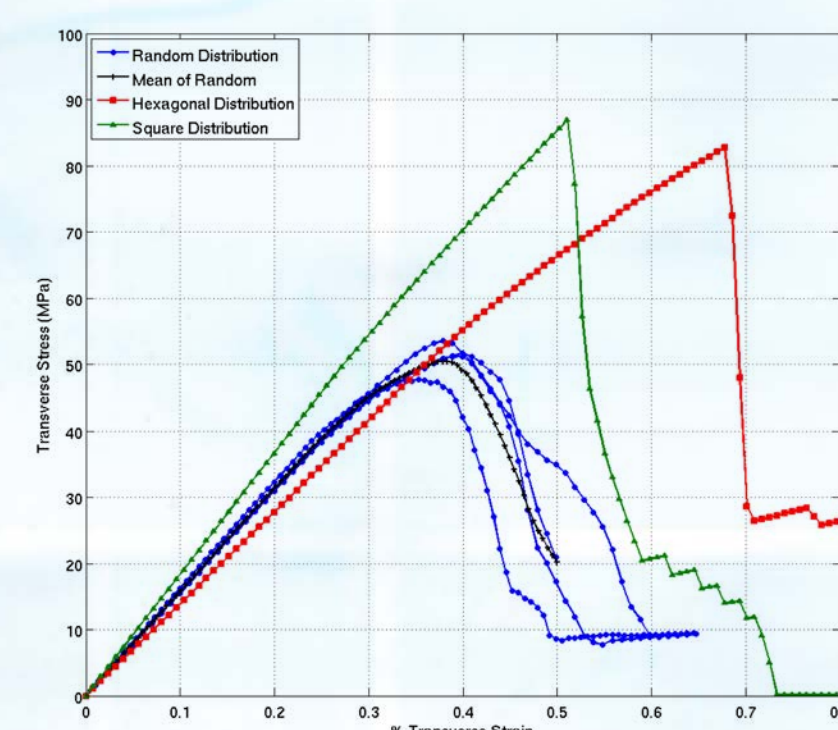


- Micromechanics are used to determine elastic properties and matrix failure
- The unit cell determines the distributed damage response (hardening) and point of fracture.
- Similar results are shown in Romanowicz, 2010



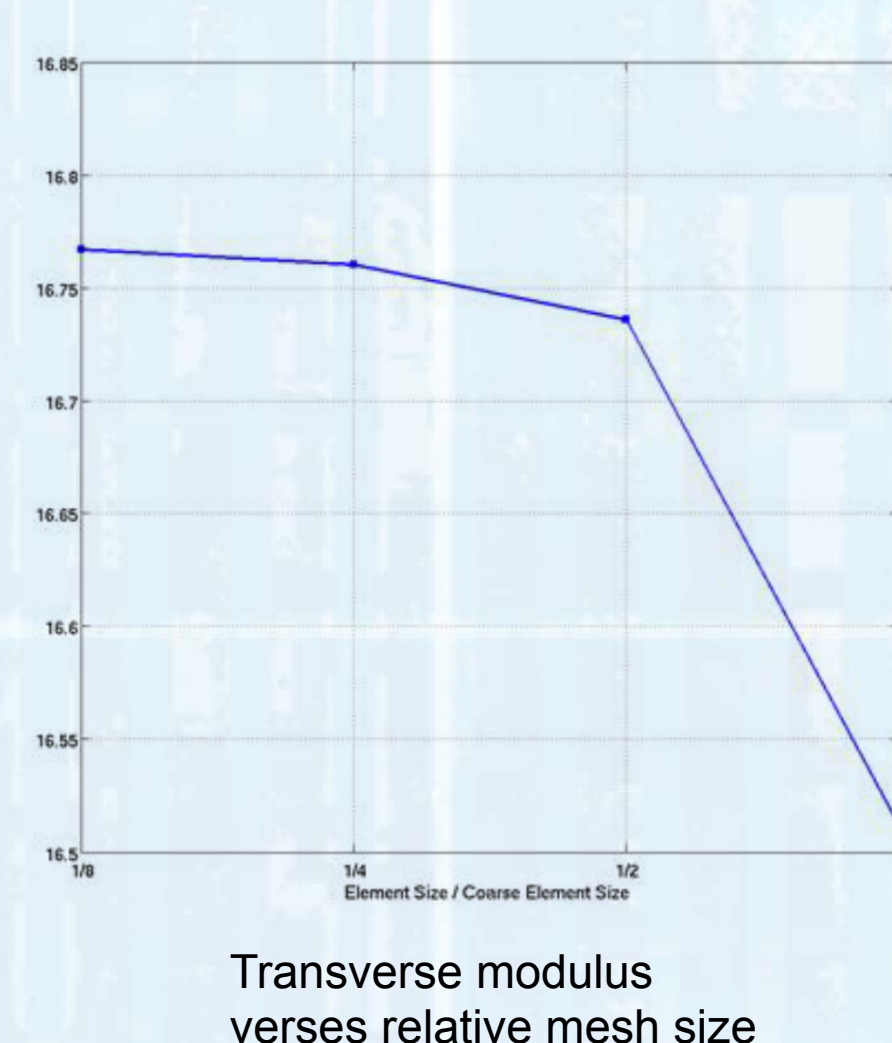
Micromechanical Simulations

- Periodic random distributions are generated from Maximal Poisson Disk Sampling with density tuning by disk injection. The distributions were obtained through collaboration with M.S. Ebeida (1441) and M.A. Scott (1442) from Sandia NM.
- Traditional structured fiber distributions accurately bound the elastic response but tend to over predict the strength and do not include the natural random structure necessary for statistically varying properties

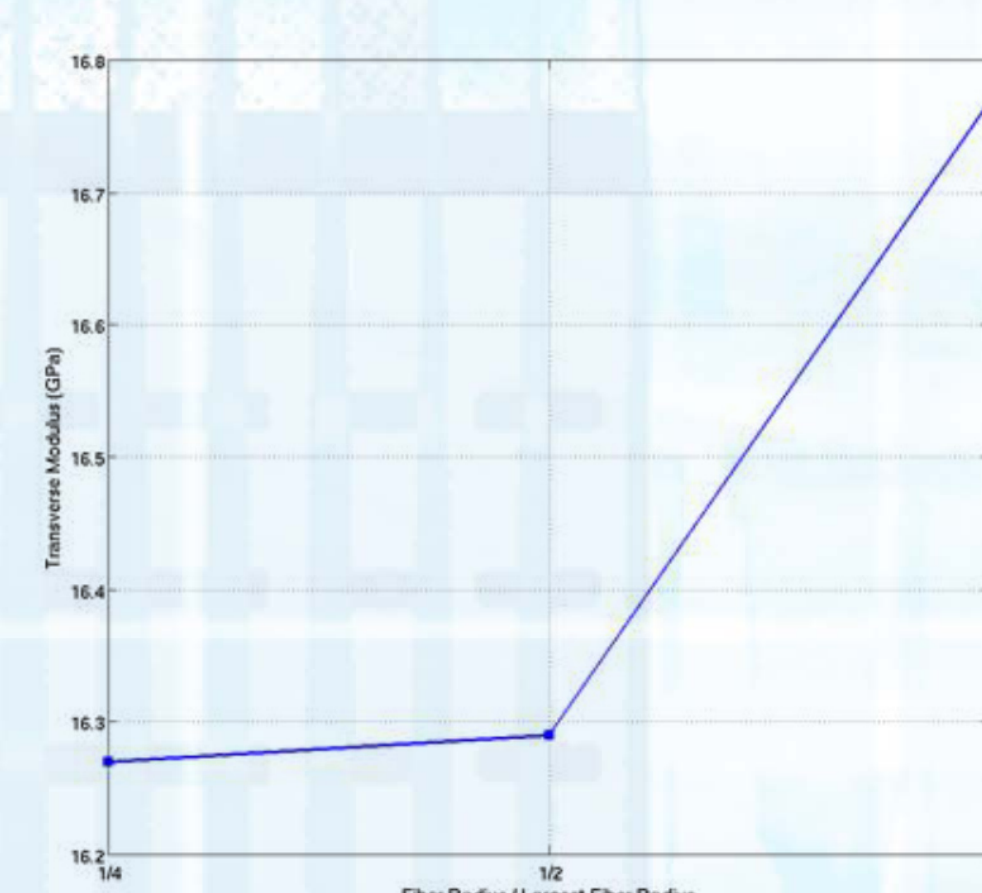


Micromechanical Simulations

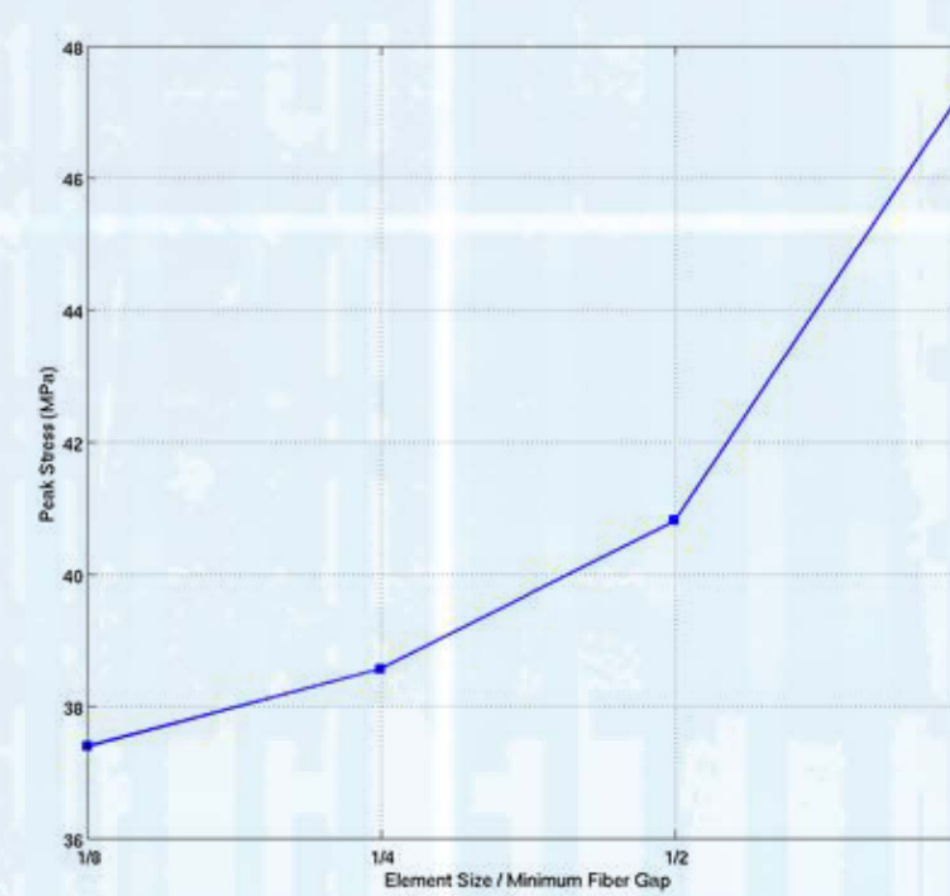
Verification: Elastic Modulus and failure stress



Transverse modulus versus relative mesh size



RVE Size is verified by adjusting the fiber radius within a unit square and comparing the transverse modulus



Transverse strength versus relative mesh size

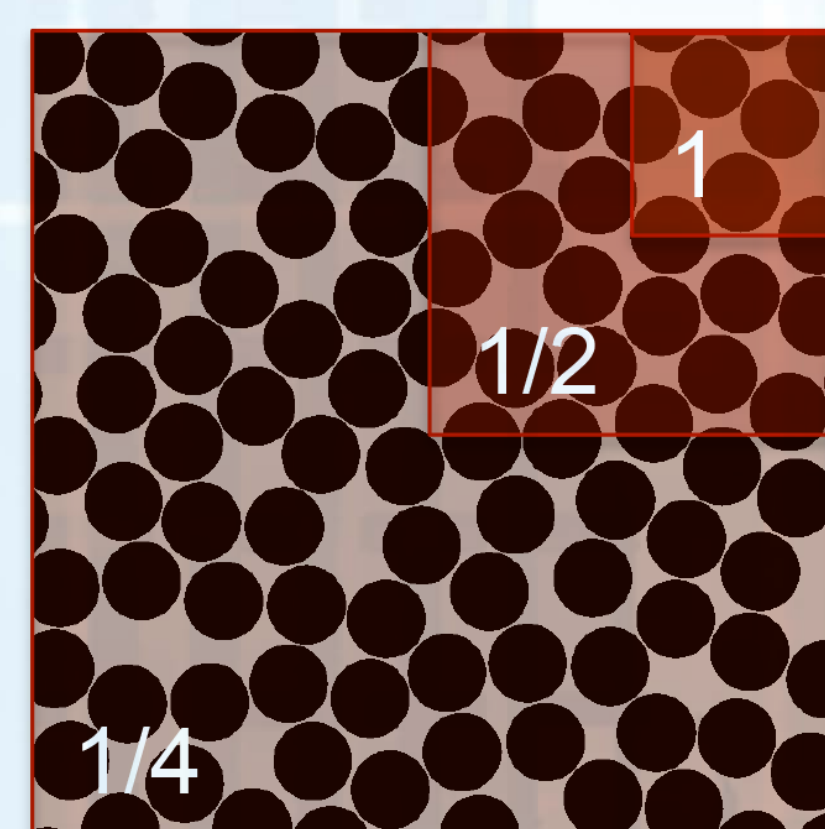
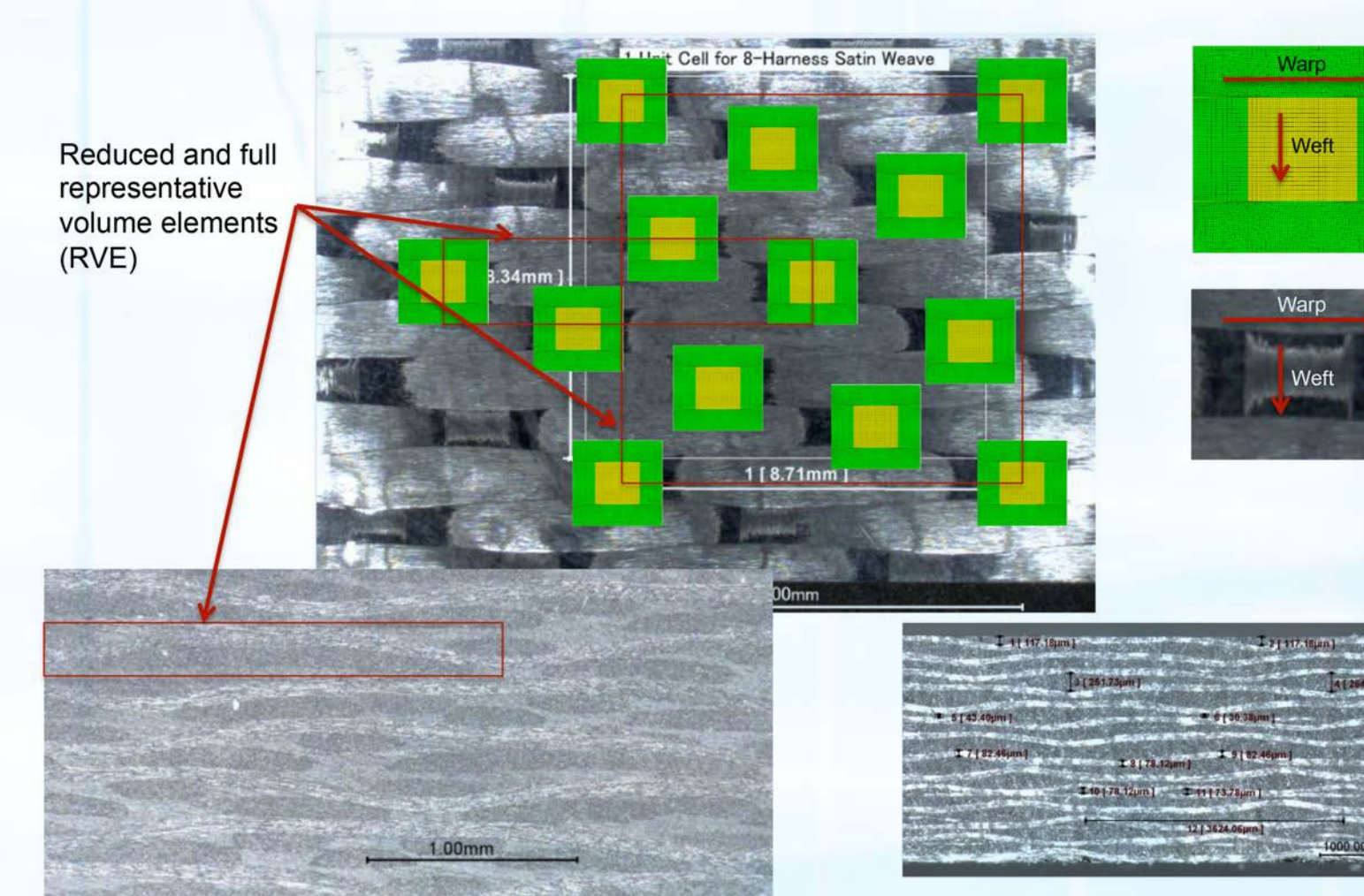


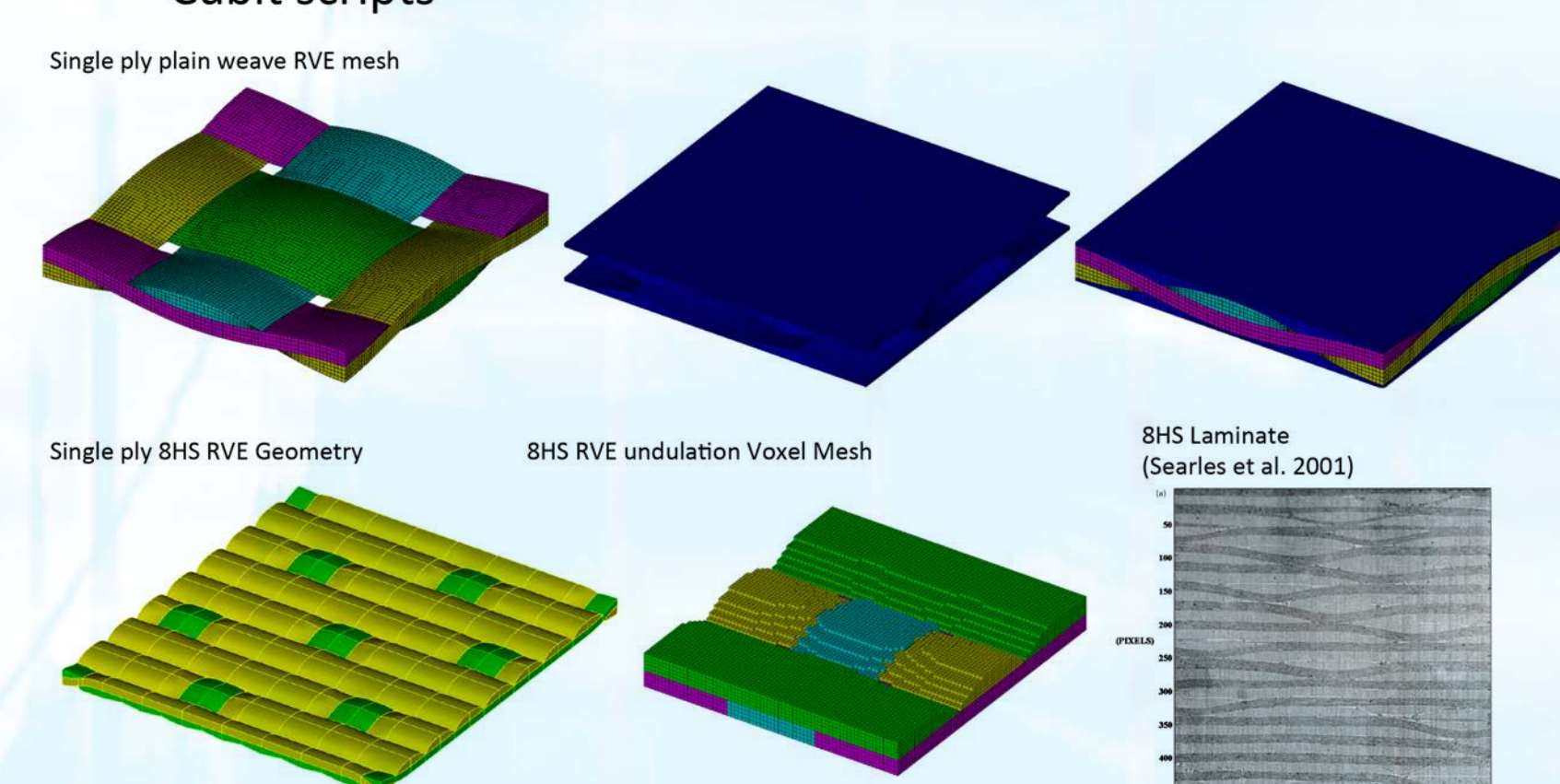
Figure showing the relative size of the RVEs

Mesomechanical simulations



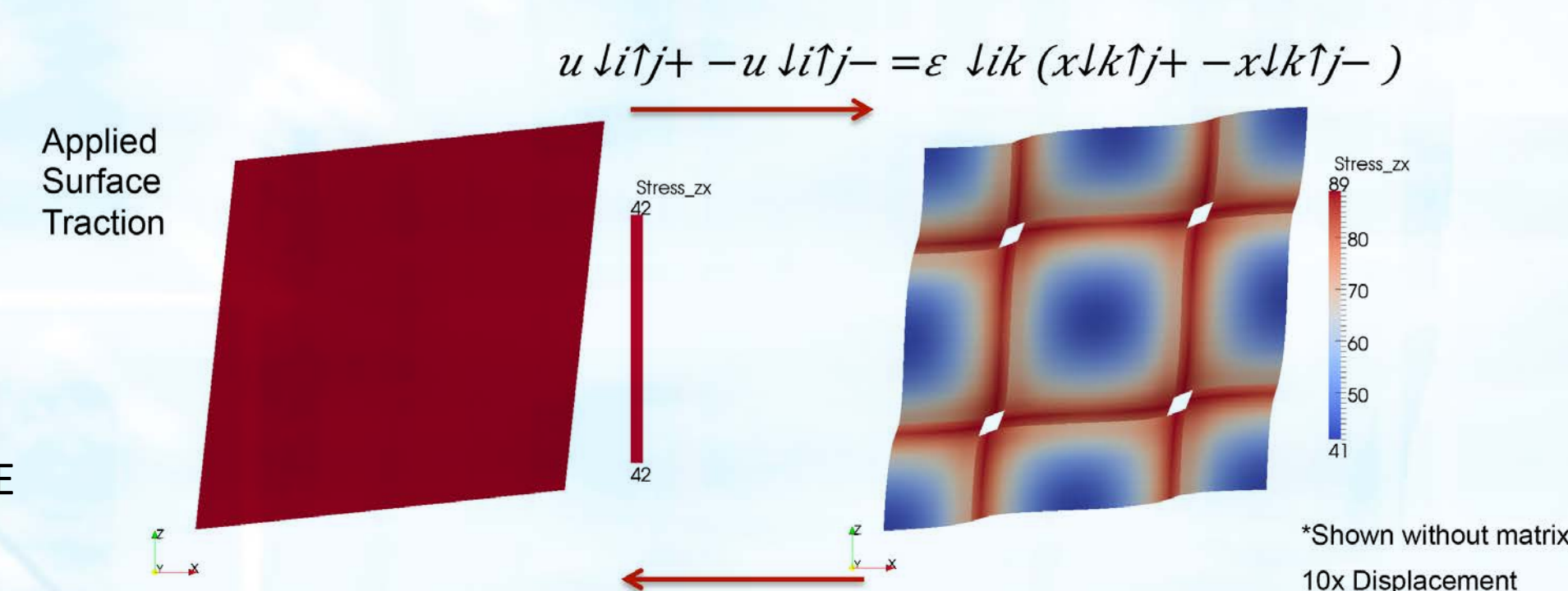
Mesomechanical simulations

- Meso-scale meshes are generated with Matlab, Python and Cubit scripts



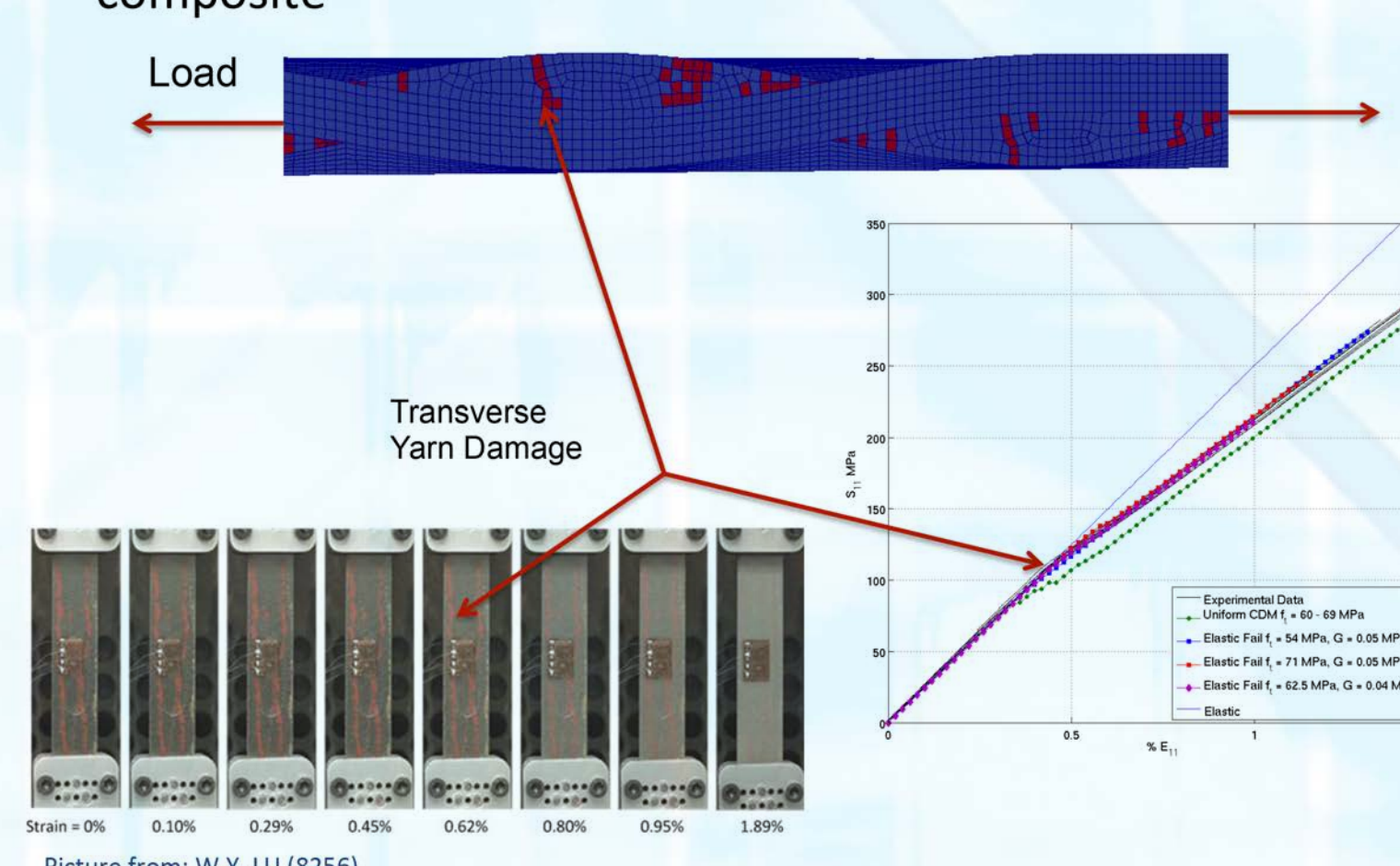
The RVE Region

- Sierra's RVE region for parameter estimation
- A reference element undergoing some prescribed kinematics
- Returns volume average stresses.
- The RVE serves as the constitutive equation for the reference model.
- The model can be given multiple RVE meshes assigned to reference elements (at random) to produce a macroscopic simulation with meso/micro details.



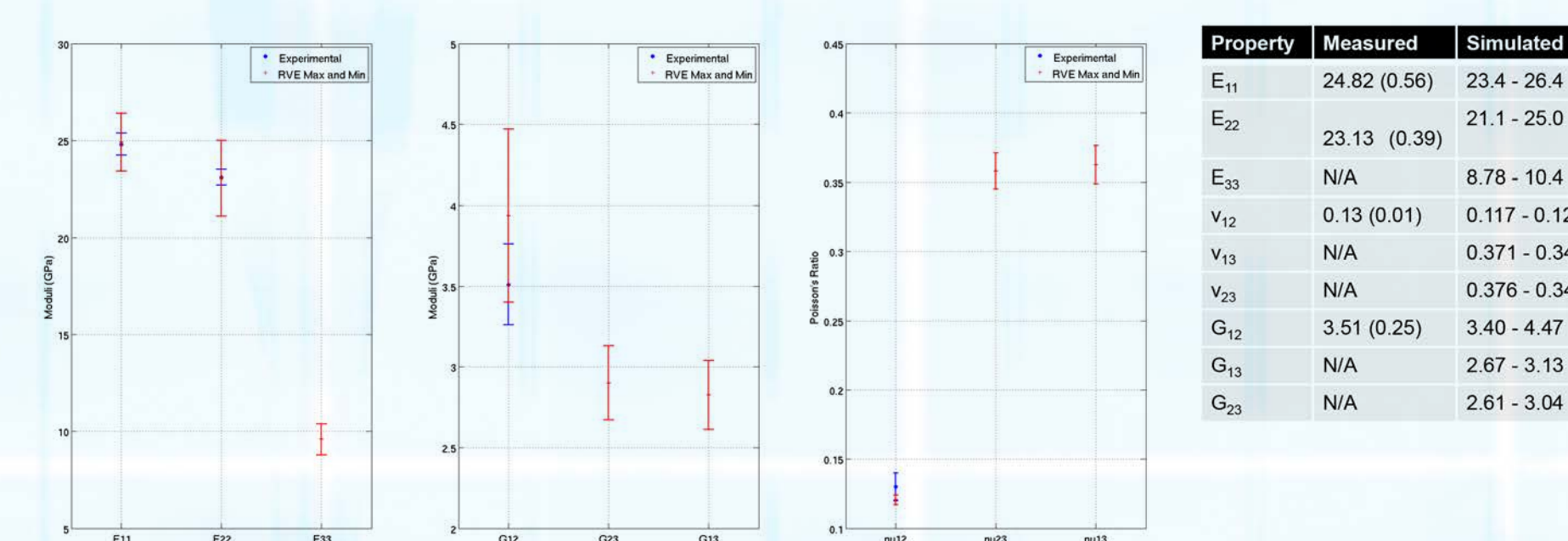
Mesomechanical simulations

Example of damage initiation and propagation in a glass fiber composite



Results: Elastic Properties Glass Fiber 8 harness satin weave

- Unidirectional (Yarn) micromechanical properties ($\nu_{lf}=0.629-0.726$)
- Micromechanical properties are given by the manufacturer or in literature as isotropic elastic fiber and elastic plastic matrix with failure.
- Properties obtained from reduced harness weave model



PREDICTIVE ENGINEERING SCIENCE PANEL



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