

# CIVIL AND ENVIRONMENTAL ENGINEERING

## DISEG - Image-based Physics-Informed Learning for Discovering Robust Constitutive Material Models

<b>Funded By</b>	Dipartimento DISEG
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<b>Context of the research activity</b>	Computational and experimental mechanics for the characterization and modelling of complex materials and structures with nonlinear and damage phenomena (e.g., elastomers, cellular and cement-based materials, 3D-printed systems, composites and metamaterials) . The project will develop an image-based framework coupled with physics-informed learning methods to simultaneously infer displacement/strain fields and interpretable, thermodynamically consistent constitutive and damage models, accounting for anisotropy, heterogeneity, and non-linear behaviour.
<b>Objectives</b>	<p>Mechanical constitutive models serve as the foundation for the design and assessment of engineering structures and components. However, traditional constitutive models are typically empirically derived for specific material classes from limited experimental observations and simplified assumptions. As a result, their calibration, transferability, and extension to emerging materials, characterized by increasing complexity, heterogeneity, anisotropy, nonlinear response, and progressive damage, remain challenging, time-consuming, and often unreliable. This limitation becomes critical as modern engineering demands materials with enhanced performance and multifunctionality to address societal needs such as sustainability, resilience, and resource efficiency. Therefore, to accelerate the safe adoption of innovative materials in real-world applications, a new paradigm for material characterization and modelling is required.</p> <p>This PhD project aims to establish an image-based, data-driven and physics-informed framework for the discovery and identification of interpretable, thermodynamically consistent constitutive and damage models directly from full-field experimental measurements. The core idea is to exploit rich kinematic information obtained from 2D stereo-camera imaging and 3D X-ray Computed Tomography (X-ray CT) to infer displacement and strain fields, while simultaneously identifying the governing material behaviour and its evolution under loading, including nonlinearities and damage accumulation. By combining full-field imaging data within modern learning, the framework enables consistent comparison and selection among competing constitutive and damage hypotheses, supporting model discovery across different</p>

materials and loading configurations, while also enhancing robustness with respect to measurement noise and data limitations.

The expected outcomes include: (i) a general methodology to extract reliable full-field mechanical information from imaging data, and (ii) validated case studies on representative complex materials (e.g., elastomers, cellular and cement-based materials, including 3D-printed systems, composites and metamaterials). Overall, the project will contribute to a scalable pathway for accelerating material characterization and enabling faster, more reliable development of constitutive and damage models for next-generation engineering materials.

**Skills and competencies for the development of the activity**

Background in civil/structural engineering, or related fields. The candidate should have solid knowledge of continuum/structural mechanics, computational modelling, familiarity with experimental mechanics and full-field measurements (e.g., DIC/DVC), and good programming skills (Python/Matlab).