PhD Program in Civil, Chemical and Environmental Engineering
Curriculum in Structural and Geotechnical Engineering, Mechanics and Materials

June 2025 Call, XLI cycle - Starting date: November 1 st 2025

The research projects submitted for the admission to the PhD program must be prepared in accordance with one of the projects listed in this file, which are organized by general thematics. Click on the Thematic you are interested in to see the full list of projects.

Projects in Structural Engineering and Mechanics

Projects in Mechanics of Materials

Projects in Geotechnical Engineering

Other Projects

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Projects in Structural Engineering and Mechanics

Project: Floor response spectra for the seismic assessment of nonstructural components in reinforced concrete buildings

Project: Structural Health Monitoring of strategic and monumental buildings assisted by new analytical, computational and intelligent methodologies

Project: Serviceability assessment of lightweight structures to human-induced vibration

Project: Wind-induced loading and dynamic response of tall buildings due to thunderstorm outflows

Project: Developments of Vortex-Induced Vibration models for engineering applications

Project: Structural response of bell towers to environmental changes

Project: Disbond of sandwich systems in aviation, fundamental solutions and stardardization

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Thematic: Structural Engineering and Mechanics

Project: Floor response spectra for the seismic assessment of nonstructural components in reinforced concrete buildings

Keywords: floor response spectra, nonstructural components, reinforced concrete buildings, Italian Seismic Monitoring Network

Brief Description:

The seismic assessment of nonstructural components (NSCs)—such as infill walls, architectural elements, machinery, and equipment housed within buildings—is a critical aspect of performance-based earthquake engineering. This is because most of the earthquake-induced damage and related economic losses are often attributed to these components. In many past major earthquakes, damage to NSCs resulted in losses that far exceeded those caused by structural damage. Moreover, such damage can severely affect the performance or functionality of critical facilities, such as hospitals. NSCs are typically classified based on their sensitivity to acceleration, deformation, or both. This PhD proposal focuses on acceleration-sensitive NSCs, for which seismic demands are commonly characterized using floor response spectra (FRS). Numerous formulas have been proposed in the literature and building codes to predict FRS for the seismic assessment of NSCs in ordinary buildings or artistic pieces hosted in monumental structures. However, these formulas are generally calibrated for specific structural typologies, raising doubts about their applicability to other building types. In this context, the proposed research aims to: (i) investigate the key parameters influencing FRS, such as higher vibration modes, structural nonlinearity, and NSC damping; and (ii) validate practitioner-oriented tools currently recommended in the literature and building codes for FRS prediction. To achieve these objectives, the study will use real data from earthquake-affected buildings monitored by the Italian Seismic Monitoring Network, in combination with parametric numerical simulations based on models calibrated using data from dynamic identification tests.

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Link to the list of projects

Thematic: Structural Engineering and Mechanics

Project: Structural Health Monitoring of strategic and monumental buildings assisted by new analytical, computational and intelligent methodologies

Keywords: Structural Health Monitoring, existing buildings, structural identification, reduced-order models, AI-assisted automatization

Brief Description:

Existing buildings, especially if credited with strategic and monumental value, require continuous and reliable structural assessment to ensure their health and safety. The issue often presents challenging tasks due to the building complexity, the material heterogeneities, and unavailability of documentation. This research proposes a novel framework for Structural Health Monitoring (SHM) that integrates traditional analytical and computational techniques with intelligent new methodologies to address these challenges. The first research stage deals with the fusion and treatment of big data collected from a rich cross-section of sample buildings through multi-physical sensor networks to establish a behavioural baseline of the structural response. The accurate picture emerging from this data-based background serves as the standing point for the second stage, aimed at solving inverse structural problems (parameter identification, modal identification, damage detection and diagnosis). The third stage deals with the standardized development of reliable and effective data-based physically-informed models. The model synthesis and mechanical representativeness will be balanced by refined techniques of reduced order modelling and model information integration (according to strategies of Modal Synthesis, Equivalent and/or Surrogate Modelling, Building Information Modeling, Stochastic Equivalent Linearization). Recurrent modeling patterns will be recognized for homogeneous typologies of buildings, considering different homogeneity classes (e.g. construction period, construction material, geometric morphology). Finally, the resulting data-based physically-informed models will be employed to simulate the structural response in the time and frequency domains, within the linear and nonlinear ranges. The simulations will allow accurate predictions of the static and dynamic effects that may follow from anthropogenic activities (e.g. conservation, restoration, refurbishment interventions), as well as the structural response to different circumstances of natural aging and/or environmental hazards (extreme natural events). Some key steps of the research path will be assisted by novel Artificial Intelligence tools (e.g. to automate the classification of anomalies in modal analysisfor damage detection). A valuable add-on will be provided by collaborations with renowned data providers (e.g. Italian Seismic Observatory of Structures) and heritage conservation authorities.

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Relevant links:

Sivori, D., Lepidi, M., Cattari, S. (2020). Ambient vibration tools to validate the rigid diaphragm assumption in the seismic assessment of buildings. *Earthquake Engineering & Structural Dynamics*, 49(2), 194-211. https://doi.org/10.1002/eqe.3235

Sivori, D., Lepidi, M., Cattari, S. (2024). Analytical identification of dynamic structural models: Mass matrix of an isospectral lumped mass model, Earthquake Engineering and Structural Dynamics, 2024, 53(8), pp. 2447–2467. https://doi.org/10.1002/eqe.4126

Sivori, D., Ierimonti, L., Venanzi, I., Ubertini, F., Cattari, S. (2023). An Equivalent Frame Digital Twin for the Seismic Monitoring of Historic Structures: A Case Study on the Consoli Palace in Gubbio, Italy, Buildings, 2023, 13(7), 1840. https://doi.org/10.3390/buildings13071840

Link to the list of projects

DICCA Ph.D. PROGRAM IN CIVIL, CHEMICAL AND ENVIRONMENTAL ENGINEERING

Thematic: Structural Engineering and Mechanics

Project: Serviceability assessment of lightweight structures to human-induced vibration

Keywords: Human-induced vibrations, Numerical simulations, Probabilistic Model, Vibration serviceability

Brief Description:

Human-induced vibration serviceability assessment of lightweight structures requires a probabilistic model of human-induced loading taking into account the variability of human walking parameters, including step frequency, arrival time, walking speed. When pedestrian density is high, human walking parameters are also affected by the interaction among pedestrians. Such an interaction can be modelled by suitable macroscopic or microscopic crowd models (e.g. the social force model). Numerical simulations can be very time consuming and not practicable at the design stage. Frequency-domain spectral models represent a valid alternative for a reliable assessment of the dynamic response.

The present research project aims to provide a reliable probabilistic model of human-induced loading on structures. A wide review of the different models proposed in the literature to schematize pedestrian interaction is expected in order to select the most suitable models to be implemented. A probabilistic characterization of human-induced loading will be derived based on numerical simulations of pedestrian traffic on domains of variable geometries representative of floors and footbridges. The final goal of the research is the introduction of a general formulation for the equivalent spectral model of the loading that can be adopted for vibration serviceability assessment of lightweight structures with variable geometrical configurations and in different traffic conditions (mono/bi-directional, unrestricted/restricted).

The project can be focused on numerical and/or experimental validation, eventually carried out in collaboration with international partners (e.g. KU Leuven, TU/Eindhoven, ULiege).

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Figure:

Link to the list of projects

***Thematic*: Structural Engineering and Mechanics**

Project: Wind-induced loading and dynamic response of tall buildings due to thunderstorm outflows

Keywords: Dynamic response, Nonstationary, Tall buildings, Thunderstorms

Brief Description:
Developing accurate models for wind loads and effects on structures is crucial to enhancing safety while minimizing costs. Given the importance of wind loads in terms of both safety and cost for tall buildings, accurately determining wind loads is essential for their design. In design codes, the calculation of wind effects on structures is based on a stationary model for the wind field, reliable for cyclonic phenomena at the synoptic scale. In regions with a mixed wind climate, thunderstorms can significantly influence design wind speeds, making their study essential for modern wind engineering. Unlike synoptic wind events, thunderstorm downbursts exhibit distinct features, including a nose-shaped mean wind speed profile and non-stationary characteristics within 10- to 60-minute time intervals.

The present Project aims to introduce suitable models for the definition of the loading and the assessment of the dynamic response of tall buildings to thunderstorms. The project involves conducting experimental work and the development of analytical models.

The experimental tests will constitute a continuation of the activities carried out within the framework of ERIES-TLTB Project. Wind tunnel tests on a benchmark tall building model will be carried out in the Giovanni Solari Wind Tunnel using an active grid to simulate both the nose-shaped mean wind profile as well as the nonstationary characteristics of thunderstorms. High Frequency Pressure Integration Tests will allow to derive the pressure distribution as well as the resultant wind loading on the building.

The analytical modelling activity involves the introduction of a statistical model for the characterization of the thunderstorm-induced wind field along a linear domain, that could be derived based on the statistical analysis of full-scale data. The model will be used to derive thunderstorm-induced loads and wind tunnel tests results will constitute a reference for comparison. The final aim is the generalization to thunderstorm-induced loading of current procedures adopted in standards to define equivalent static wind loading, that are formulated with reference to the synoptic wind model.

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Relevant links: https://eries.eu/

Figure: CAARC Building model in the Giovanni Solari Boundary Layer Wind Tunnel

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Thematic: Structural Engineering and Mechanics

Project: Developments of Vortex-Induced Vibration models for engineering applications

Keywords: Aerodynamics, Aeroelasticity, Experimental tests, Reduced-order models, Vortex-Induced Vibrations

Brief Description:

Vortex-Induced Vibrations (VIVs) represent one of the most important issues concerning wind excited slender structures in both air and water. Despite its great significance, the engineering description of this phenomenon mainly relies on experimental evidence and empirical models.

Engineering verifications (e.g., EN 1991-1-4, 2005, 2010) commonly use two calculation procedures. The spectral model (Vickery & Basu 1983, J Wind Eng Ind Aerodyn 12(1), 49-74) supplies an analytical expression for an equivalent aerodynamic damping; the harmonic model (Ruscheweyh 1994, In: Sockel, Wind-Excited Vibrations of Structures. Springer-Verlag, Wien) supplies a vortex-induced force. The spectral formulation is considered sounder, more prudential and more reliable at high Scruton numbers, where the response tends to be in the so-called "forced vibration" regime. Both formulations may involve considerable uncertainties compared to full-scale measurements. Recent developments suggest that a classic van der Pol formulation, as used in the spectral model, may no longer be reliable (e.g., Lupi et al. 2021, J Wind Eng Ind Aerodyn 208 104438, Guo et al. 2022, J Wind Eng Ind Aerodyn 221 104887).

However, engineering applications often need extreme simplifications, the reliability of which has not yet been adequately explored. There are also classes of slender structures, such as chimneys, tubular poles and super tall buildings, in which resonant vortex shedding can be resonant with higher vibration modes, leading to intense vibrations and fatigue damage. In this case, the spectral method does not yet find a codified procedure, effectively making this procedure unusable. Moreover, several issues are still open, such as the choice of the limiting vibration amplitude in the lock-in regime and the estimation of the peak coefficient in transient regime.

With particular reference to the spectral method, the proposed project will investigate developments for technical applications, focusing on the parameters whose choice is crucial in the response calculation of lightweight, low-damped systems, as well as on the generalization to higher vibration modes. The project may include experimental tests carried out in the "Giovanni Solari" Wind Tunnel (GS-WT)

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Link to the list of projects

Thematic: Structural Engineering and Mechanics

Project: Structural response of bell towers to environmental changes

Keywords: masonry structures, bell towers, thermal actions, monitoring, structural safety

Brief Description:

The structural response of predominantly vertical structures (civic towers or bell towers) is conditioned by multiple factors, in which variations in environmental parameters play a significant, albeit often underestimated, role. In this context, the monitoring data available on numerous bell towers show how displacements and consequently the state of stress is influenced in a non-negligible manner by thermal variations induced by solar radiation. The different levels of insolation that can be affected on the walls of the same structure, characterized by a prevalent vertical development determines deformations and consequently, depending on the thermal expansion coefficient, different stress states between the different walls, which can interpret the cyclic and seasonal movement of multiple bell towers. The project, starting from the study of the monitoring data of the Garisenda Tower and the Asinelli Tower in Bologna (Italy), aims to understand and interpret how the thermal variation detectable daily and seasonally on the two towers conditions the global displacements of the two artefacts.

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Link to the list of projects

Thematic: Structural Engineering and Mechanics

Project: Disbond of sandwich systems in aviation, fundamental solutions and stardardization

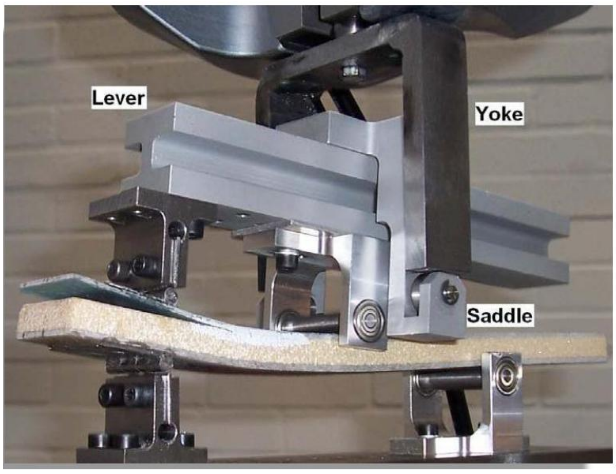
Keywords: sandwich composites; characterization of material properties; standardization.

Brief Description:
The aim of the project is to derive fundamental solutions based on elasticity, structural mechanics, linear elastic fracture mechanics and nonlinear fracture mechanics to complement and support experimental work for the characterization of the resistance to disbond fracture of sandwich composites (static and fatigue) used in aviation (see CMH17, Composite Mechanics Handbook 17). The work is part of *Horizon Europe Project DESIGN - Evolutions of airworthiness standards for new aircraft structure designs using materials, processes, and advanced manufacturing methods*, aimed at developing key enablers for safe design and use of sandwich structures in principal structural elements applications in aviation.

The PhD student will participate to the activities of an international team of researchers including, in addition to UniGE, various European Universities/research centers (DTU, Fraunhofer IMWS) and companies (Airbus Helicopters, Airbus commercial Aircraft, Leonardo, NSE Composites, Dupont.

Referent: Roberta Massabò (Roberta.massabo@unige.it)

Figure: Mixed Mode Bending Sandwich specimen (courtesy by DTU)



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Projects in Mechanics of Materials

Project: AI-Driven Meta-Modelling of Bio-Inspired Thermal Energy Storage Harvesters made of Low-Carbon Cementitious for the Built Environment

Project: Peridynamic modeling of biological materials

Project: Advanced design of avant-garde active microstructured metamaterials

Project: Disbond of sandwich systems in aviation, fundamental solutions and stardardization

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Thematic: Mechanics of Materials

Project: AI-Driven Meta-Modelling of Bio-Inspired Thermal Energy Storage Harvesters made of Low-Carbon Cementitious for the Built Environment

Keywords: AI-driven modelling; Low-carbon cementitious composites; Phase change materials (PCMs); Bio-inspired design; Topology optimization; Multiscale homogenization; Reduced-order modelling (ROM); Thermal energy storage (TES); Green concrete; Thermal metamaterials; Physics-informed machine learning.

Brief Description:
This PhD project offers an opportunity to explore AI-driven, multiscale modelling and digital twin development for bio-inspired thermal energy storage (TES) systems, made of low-carbon cement composites and embedded phase change materials (PCMs).
This PhD call offers an exploration of AI-driven, multiscale modelling and digital twin development for bio-inspired thermal energy storage (TES) systems using low-carbon cement and embedded PCMs. The candidate is call to meta-design TES units enabling meta heat transfer and structural integrity.
The work will integrate:

- Topology optimization (SIMP, level-set) under coupled mechanical and enthalpy-based models.
- Multiscale homogenization (i.e., FE^2 and FFT-based methods) to derive effective thermal-mechanical laws.
- Reduced-order modelling (ROM) and real-time digital twins, embedding sensor feedback to adapt geometry and predict behaviour under cyclic thermal loads.
- Physics-based machine learning (ϕML-TES) or similar for inverse design and manufacturability control, delivering STL/STEP files directly to 3D-printing.
- Key performance outputs can include i) energy harvesting/efficiency parameters, ii) TES_{meta}-parameters, iii) $\sigma_{max}/\sigma_{allo}$wed stress-level, iv) CO_2-eq saving via LCA tools.

This work offers cross-disciplinary training in advanced numerical methods, AI, optimization, materials science, and sustainable design.

References:

1. Caggiano, A., Peralta, I., Fachinotti, V. D., Goracci, G., & Dolado, J. S. (2023). Atomistic simulations, meso-scale analyses and experimental validation of thermal properties in ordinary Portland cement and geopolymer pastes.
2. Fachinotti, V. D., Peralta, I., Toro, S., Storti, B. A., & Caggiano, A. (2023). Automatic generation of high-fidelity representative volume elements and computational homogenization for the determination of thermal conductivity in foamed concretes. Materials and Structures, 56(10), 179.
3. Fachinotti, V. D., Álvarez-Hostos, J. C., Peralta, I., Zanjani, M. K., Berardi, U., Pisello, A. L., ... & Caggiano, A. (2024). Reviewing numerical studies on latent thermal energy storage in cementitious composites: report of the RILEM TC 299-TES. Materials and Structures, 57(10), 247.
4. Hostos, J. C. Á., Storti, B., Lefevre, N., Sobotka, V., Le Corre, S., & Fachinotti, V. D. (2023). Design via topology optimisation and experimental assessment of thermal metadevices for conductive heat flux shielding in transient regime. International Journal of Heat and Mass Transfer, 212, 124238.

Referents: Prof. Antonio Caggiano, antonio.caggiano@unige.it , DICCA-UniGE, Scopus =54916174800
Co-Referent: Dr. Juan Hostos (CIMEC-CONICET, Argentina), Scopus =56925352200

A key aspect of the project is the collaborative opportunity for PhD candidates, which includes up to 18 months of mobility abroad through partnerships with international institutions. The call is also open for a Double PhD program, allowing candidates to earn degrees from both UniGE and partner universities.

Link to the list of projects

Thematic: Mechanics of Materials

Project: Peridynamic modeling of biological materials

Keywords: Non-local continua; Constitutive models; Cutting; Soft-tissues; Multi-scale; Microstructure

Brief Description:

Peridynamics is a non-local theory that is designed to unify the mechanics of discrete and continuous media and has shown promise in modeling complex material behaviors at different scales. Rather than using partial differential equations to formulate the equations of motion, peridynamics uses integral equations which exist on crack surfaces. This aspect lends itself to the description of modern problems in mechanics involving damage and spontaneous formation of cracks/discontinuities. Furthermore, the material horizon introduce a strong non-local character which may result of fundamental importance for reproducing microstructural effets and for modelling modern multi-scale problems. Peridynamic theory postulates that material points interact through pair-potentials (bond-based formulations) or multi-body potentials (state-based type formulations). Notably, a special class of peridynamic models, known as correspondence models, provide a bridge between classical continuum mechanics and peridynamics. These models are particularly useful because they allow well-established local constitutive theories to be used within the nonlocal peridynamic mathematical framework. Peridynamics has been used to model diverse phenomena in biomechanics ranging from fracture to aspects of growth and remodeling. Moreover, because the peridynamic framework deals comfortably with both continuous and discrete media, it is a compelling method for modeling biological tissue on the cell population scale where the material is, in reality, somewhere in-between.

The aim of this project is to develop advanced finite deformation peridynamic material models for biological materials providing a rigorous mathematical foundation along with a robust, open, and extendable computational framework of wide applicability for challenging problems in mechanics of materials, computational mechanics and biomechanics.

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Relevant links: Link1; Link2

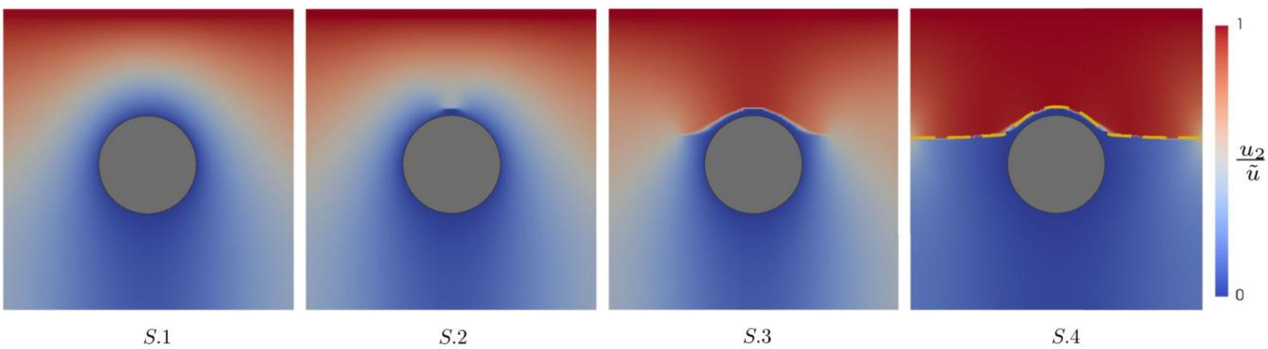

Figure: Discontinuity evolution in a heterogeneous material modeled using peridynamics (Diana V., *Archives of Computational Methods in Engineering* (2023) 30:1305–1344).

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Thematic: Mechanics of Materials

Project: Advanced design of avant-garde active microstructured metamaterials

Keywords: Active metamaterials, hierarchical architected microstructure, multi-field physical phenomena, non-local dynamic homogenisation

Brief Description:

The design of technologically innovative materials with enhanced or exotic mechanical properties constitutes an area of significant interest in Mechanics. Important results have been obtained with the development of artificial composite materials, a combination of different ingredient materials spatially organised according to avant-garde innovative and optimised topologies. Artificial architected heterogeneous materials and active metamaterials with extreme mechanical performances can be obtained with active periodic microstructures with empty spaces and cavities properly designed. Developments in this open research field still appear to be very promising, as evidenced by the current extensive literature on the subject and the new challenges that result from it. Moreover, the conceptualisation and the tailored optimal design of innovative materials with complex microstructures, for cutting-edge and smart applications in many engineering and technological fields, are also fueled by recent developments in the technological fields of high-precision microengineering and high-fidelity additive manufacturing.

Within this framework, the present PhD research project focuses on developing technologies that pave the way to almost endless opportunities for designing avant-garde active materials and metamaterials that can be activated in a controlled fashion to change shape, configuration, or physical properties in response to external stimuli. Advancement of knowledge concerns the conceptualisation, modelling, and design, together with prototyping and proof-of-concept of reprogrammable multi-functional metadevices for wave propagation control, energy harvesting, sensing, and stress-controlled failure programs. Physical-mathematical analytical formulations will be exploited to establish the governing equations, which will be solved by means of analytical and computational methods. Enhanced multi-field homogenization/continualization schemes will be conceptualised for a thermodynamically consistent constitutive characterisation of active hierarchical metamaterials with complex architected microstructure. Theoretical results will be optimised via homogenization-based optimisation numerical schemes and verified by virtual testing.

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Link to the list of projects

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Thematic: Mechanics of Materials

Project: Disbond of sandwich systems in aviation, fundamental solutions and stardardization

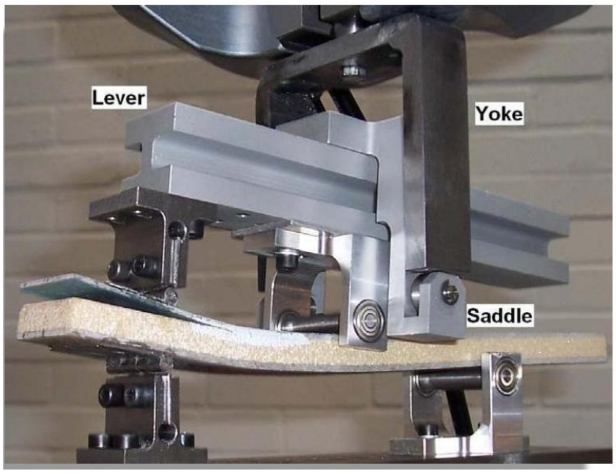
Keywords: sandwich composites; characterization of material properties; standardization.

Brief Description:
The aim of the project is to derive fundamental solutions based on elasticity, structural mechanics, linear elastic fracture mechanics and nonlinear fracture mechanics to complement and support experimental work for the characterization of the resistance to disbond fracture of sandwich composites (static and fatigue) used in aviation (see CMH17, Composite Mechanics Handbook 17). The work is part of *Horizon Europe Project DESIGN - Evolutions of airworthiness standards for new aircraft structure designs using materials, processes, and advanced manufacturing methods*, aimed at developing key enablers for safe design and use of sandwich structures in principal structural elements applications in aviation.

The PhD student will participate to the activities of an international team of researchers including, in addition to UniGE, various European Universities/research centers (DTU, Fraunhofer IMWS) and companies (Airbus Helicopters, Airbus commercial Aircraft, Leonardo, NSE Composites, Dupont.

Referent: Roberta Massabò, Roberta.massabo@unige.it

Figure: Mixed Mode Bending Sandwich specimen (courtesy by DTU)



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Projects in Geotechnical Engineering

Project: SUNRISE: Sustainable Use of Non-saturated soils for Resilient Infrastructure and Solar Energy

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Thematic: Geotechnical Engineering

Project: SUNRISE: Sustainable Use of Non-saturated soils for Resilient Infrastructure and Solar Energy

Keywords: Solar panel foundations, pile-soil interactions, combined loading, unsaturated soils, resilience of critical infrastructure

Brief Description:

After the COP21 agreement in Paris, the European Union (EU) has been undertaking a significant economic and legislative effort to achieve carbon neutrality by 2050. The energy transition is one of the most important strategies to reach this goal. The aim is to shift from a fossil fuel-based energy system to a diversified low-carbon mix, relying on renewable energy sources such as wind, solar, wave, and low-enthalpy geothermal energy.

The growing global demand for renewable electricity generation and distribution has recently spurred extensive research to improve the efficiency and resilience of these critical infrastructures. Among the available sources, solar energy is the most widespread thanks to its low environmental impact, reduced costs, and high exploitation potential. In the EU, solar panels generate up to 10% of the total electricity and account for approximately 50% of the electricity produced from renewable sources.

Solar panel foundations are typically made of short driven steel piles. These piles are primarily subjected to lateral and uplift forces induced by wind acting on the superstructure (i.e., the solar panels). Given their short embedment length, these piles transfer the load to the surrounding soil, which is often above the groundwater table and therefore in a partially saturated condition. In this state, the soil is highly sensitive to changes in pore pressure and degree of saturation resulting from groundwater table oscillations and/or intense rainfall events. Therefore, a thorough understanding of the interaction between the pile, the surrounding unsaturated soil, and the environmental conditions is of paramount importance for advancing design practices and enhancing the resilience of both new and existing solar energy infrastructures.

Despite this need, current design guidelines are based solely on site-specific trial tests, where the presence of pore water is only considered in relation to corrosion risks. This practice presents several limitations, including the lack of a rational design methodology and a strong dependence of pile capacity on the season when testing is conducted.

This project aims to bridge this practical knowledge gap by providing a rational design methodology that accounts for soil–foundation interaction under evolving environmental conditions.

The proposed research focuses on a comprehensive understanding of soil–pile interaction under combined mechanical loads and environmental conditions, such as groundwater table fluctuations, through the integration of centrifuge testing and advanced numerical modelling. Additionally, developing in-depth knowledge of soil–structure interaction under partially saturated conditions is a crucial first step toward evaluating the resilience of these geotechnical structures, specifically the piled foundations, under changing climate conditions.

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Other Projects

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