Doctoral Programme in Civil, Environmental and Mechanical Engineering

Research subjects proposed for the 41st cycle – second call

A mandatory attachment of the application is a description of the research project (max 4 pages) relative to the research areas of the Doctoral Programme in Civil, Environmental and Mechanical Engineering, preferably on one of the research themes suggested below. Candidates applying for a scholarship on a reserved topic (with an ID and in red) must write a project proposal related to the specific topic of the scholarship.

Curriculum A - Civil and Environmental Engineering

- *Reference person:* Giuseppe Pedone (UNITN/DICAM)

Title: Analysis and prediction of rainfall-induced slope instabilities for landslide risk mitigation

Rainfall-induced landslides are recurrently observed across the globe, often causing casualties, injuries and significant damages to structures and infrastructures (Gens, 2007; Alonso, 2017). Italy is one of the countries most severely affected by slope instabilities (APAT, 2007), as demonstrated by well documented case studies reported in the literature, spanning from deep and slow landslides (Pedone et al, 2022) to shallow and fast phenomena (Pirone et al, 2025).

Even when the main factor triggering slope instabilities is identified (e.g. rainfall infiltration), predicting slope instability events remains extremely challenging. As a consequence, several areas are exposed to a very high landslide risk (e.g. 14% of the Autonomous Province of Trento is affected by sizeable landslide movements; APAT, 2007). After their trigger, landslides can cause large displacements of significant soil volumes (the so-called run-out process). Predicting the movements of these large soil masses represents another major challenge, that would eventually allow to reduce human and economic losses (e.g. 2022 Ischia landslide; Romeo et al, 2023).

The present research proposal aims at improving the current state-of-the-art in terms of rainfall-induced landslide analysis and prediction. To this aim, reference case studies located in southern Italy will be considered, for which preliminary monitoring data have been already collected and geotechnical laboratory characterisations have been started as part of ongoing collaborations between the University of Trento and other national Universities. Additional data will be collected and used to inform advanced 2D and 3D hydro-mechanical slope stability analyses, allowing to investigate the impact of extreme rainfall events on slope stability.

The proposed research project will leverage a unique set of field and laboratory data referred to widely investigated rainfall-induced landslides, certainly leading to original outcomes that will be of interest for the civil and environmental engineering community. Innovative approaches for landslide activity predictions are also expected to be delivered at the end of the project, based on advanced 2D and 3D slope stability analyses performed, for instance, by combining Finite Element Method (FEM) and Material Point Method (MPM) approaches (e.g. Ceccato et al, 2024). Similar analyses have been rarely reported in the literature, especially with reference to real and well-documented case studies (e.g. Sitarenios et al, 2021).

The above-mentioned research activities will be conducted in collaboration with colleagues from national and international Institutions. Research findings will be shared on geotechnically-oriented high-impact journals and during relevant international peer-reviewed conferences. The PhD candidate will certainly develop academic writing and presentation skills, as well as technical and non-technical, hard and soft skills, to fully develop professionally and prepare the ground for future challenges, both in academia and industry.

References:

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- Pedone G, Tsiampousi A, Cotecchia F, Zdravkovic L, 2022. Coupled hydro-mechanical modelling of soil-vegetation-atmosphere interaction in natural clay slopes. *Canadian Geotechnical Journal*, 59(2), 272-290.

- Pirone M, Vitiello G, Pedone G, Casini F, Santo A, Urciuoli G, 2025. The PROMISE project: An integrated approach for mitigation of flowslide risk – Preliminary results from the Salerno test site. *EUNSAT 2025 Conference*, Lisbon, 1-3 September 2025.

- Romeo S, D'Angiò D, Fraccica A, Licata V, Vitale V, Chiessi V, Amanti M, Bonasera M, 2023. Investigation and preliminary assessment of the Casamicciola landslide in the island of Ischia (Italy) on November 26, 2022. *Landslides*, 20, 1265-1276.

- Sitarenios P, Casini F, Askarinejad A, Springman S, 2021. Hydro-mechanical analysis of a surficial landslide triggered by artificial rainfall: the Ruedlingen field experiment. *Géotechnique*, 71(2), 96-109.

- *Reference person:* Marco Tubino (UNITN/DICAM)

Participants: Guido Zolezzi (UNITN/DICAM), Niccolò Ragno (UNITN/DICAM)

A1 - scholarship on reserved topics

Funded by: MUR (Italian Ministry of University and Research) – Dipartimenti di Eccellenza (Departments of Excellence) Project - "Dipartimenti di Eccellenza 2023-2027 (Legge 232/2016)", CUP n. E63C22003880001".

Title: Sediment regime and evolutionary trajectories of riverine ecosystems

Project description: Rivers are among the most threatened ecosystems of the world and are impacted more and more by human activities. Rivers are strongly connected with other components of the earth system by exchanging water and sediment and by responding to alterations such as climate change, growth of vegetation, building of in-stream structures and gravel mining activities. This connectivity invariably leads to changing conditions on a multitude of temporal scales, from the daily scale (e.g., discharge variation due to precipitations or water releases), to the scales of decades or centuries (e.g., climate change, alterations of the sediment production in the basin). As a result, rivers are often out of equilibrium and follow morphodynamic trajectories, depending on intensity, duration, and nature of stressors. Their role as fundamental connecting agents of the evolving landscape is underpinned by the morphological dynamics, which results from the combined effect of processes acting at multiple scales, from the grain to the catchment. Channel geometry and patterns reflect the ongoing adjustment to fluctuating flow and sediment yields (bedload/suspended load) and, consequently, the balance of erosional and depositional processes. Sediment management in fluvial and tidal networks is of crucial importance for environmental, productive and safety reasons. The loss of sediment connectivity along river networks is recognized as a major cause of habitat degradation and biodiversity loss, while erosion/deposition processes may severely contribute to flood hazards. Specifically, in alpine regions, the impact of sediment deficits is responsible for riverbed incision and related habitat degradation. At the same time, increase in sediment load and transport is a major problem in regions with soil erosion due to intensive agriculture. Consequences of sediment deficits and impacts on the river are decrease in habitat heterogeneity, risk of river bank erosion and of damage to infrastructure, lack of spawning habitats for fish species and depauperate macroinvertebrate fauna, decrease in sediment turnover rates and river type-specific sediment quality, risk of channel avulsion during extreme events.

In the last 40 years our understanding of morphodynamics has been remarkably advanced through mathematical theories and predictive models, which have received strong validation from laboratory scale experiments and more recently also from field observations. Theoretical models can now benefit from the remarkable support of satellite information, which provides an unprecedented capability of performing quantitative analyses of the spatial distributions of river and deltas characteristics and evolutionary trajectories. The morphodynamic processes that determine the shape of the river have been mainly studied under the assumption that the river system is in dynamic equilibrium. Furthermore, most of the existing morphodynamic models refer to the reach scale, i.e. a hydro-morphologically homogeneous portion of the channel, though processes at this scale are clearly conditioned by those occurring at hierarchically higher scales. Disequilibrium between sediment supply and transport capacity and the presence of evolutionary trajectories, as well as the morphodynamical response to a variable flow regime, such as the hydrological cycle, are still to a large extent unexplored.

- *Reference persons:* Gianni Andreottola (UNITN/DICAM), Luca Fiori (UNITN/DICAM)

A2 - scholarship on reserved topics

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering.

Title: Combination of CAD (Cascade Anaerobic Digestion) with HTC (Hydrothermal Carbonization) for improving energy recovery from residual biomasses and valorization of hydrochar for quaternary treatment of municipal wastewater

Anaerobic digesters used in large-scale wastewater treatment plants (>150,000 PE) are generally designed as completely mixed reactors (CSTR) in single-stage or two-stage configurations. While this setup offers structural and operational simplicity, it presents significant limitations such as limited hydrolysis efficiency, leading to reduced volatile solids (VS) conversion. Sensitivity to operational variations can negatively impact biogas production, while large reactor volumes and low organic loading rates (OLR) result in low energy efficiency.

An innovative solution, supported by scientific literature and recent full-scale applications, is the adoption of cascade anaerobic digesters (CAD). This configuration allows for a reduction of hydraulic retention time (HRT) by over 50% and an increase in organic loading rate by 100%. It also leads to higher volatile solids reduction, exceeding 50%, and an increased biogas production of 15-20%. Furthermore, it enables the treatment of larger sludge volumes, enhancing energy valorization potential.

To further improve biogas production, this PhD project will also investigate the combination of CAD systems with hydrothermal carbonization (HTC). HTC can act both as a pretreatment to hydrolyze the residual biomass before anaerobic digestion and as a post-treatment to reduce the volume and mass of the digestate produced. Interestingly, the liquid fraction recovered from HTC – and eventually also some hydrochar - can be recycled back to the CAD system to increase the biogas production.

Finally, the hydrochar produced through HTC will be converted into activated carbon through pyrolytic and activation stages and used in the quaternary treatment of urban wastewater to remove organic micropollutants.

This integrated approach aims to enhance both energy recovery and environmental sustainability in wastewater treatment processes.

Research outcomes of this PhD research project will be publications in high impact factor journals focused on waste management and production of sustainable materials from bioresources and biowaste.

- *Reference person:* Marco Broccardo (UNITN/DICAM)

Participants: Oreste S. Bursi (UNITN/DICAM), Ziqi Wang (UC Berkeley)

A3 - scholarship on reserved topics

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering.

Title: Regional Simulation of Stochastic Ground Motions Accounting for Site and Path Effects

Introduction

Earthquakes are among the most destructive natural disasters, with socio-economic impacts extending across spatially distributed buildings and lifeline infrastructure. It is imperative to understand the collective vulnerabilities, intra- and inter-system dependencies, and potential consequences across an entire geographical region. **Such an understanding necessitates regional-scale ground motion prediction.** Traditional stochastic ground motion models (GMMs) often rely on ergodic assumption, failing to account for capture regional ground motion variability. This project aims to develop a regional stochastic ground motion simulation framework that explicitly incorporates site- and path-dependent effects, improving the representation of ground motion variability for regional seismic hazard analysis.

Research Objectives

The proposed research aims to:

- Develop the first regional stochastic ground motion simulation model by incorporating site- and path-dependent effects into the site-based stochastic GMM framework.
- Incorporate two layers of spatial dependencies in ground motion variability, including (i) parameter dependencies using copula-based joint probability models and (ii) white-noise dependencies using (time-varying) coherency functions.
- Calibrate and validate the model using recorded ground motion databases or physics-based synthetic databases.

- Apply the developed model for seismic hazard assessment, including soil and site effects, shedding light on the uncertainty quantification methodologies.
- Evaluate model performance by comparing it against traditional ground motion selection approaches.
- A hybrid ground motion model, merging conditional mean spectrum approaches with random vibration-based stochastic models under a unified UQ framework.

Expected Contributions

- Three/four research papers
- National and International conferences
- Open-source simulation tools (on MATLAB and/or Python and/or Julia) for researchers and practitioners.

Timeline

- Year 1: Literature review, dataset collection, and initial model development.
- Year 2: Model calibration, validation, and uncertainty analysis.
- Year 3: Application to seismic hazard assessment and thesis writing.

- *Reference person:* Daniel Zugliani (UNITN/DICAM)

Participant: Giorgio Rosatti (UNITN/DICAM)

A4 - scholarship on reserved topics

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering

Title: Bridge clogging by loose sediments during hyper-concentrated and debris flow events: modelling strategies, experimental validation and related aspects

Bridge clogging by loose sediments during hyper-concentrated and debris flow events can profoundly affect the development of the sediment-dominated flooding processes, causing overflows. Hazard (and risk) mapping should properly consider this phenomenon to provide reliable predictive scenarios. Therefore, the clogging process must be adequately reproduced by numerical models. Despite the importance of the topic in mountain regions and the possible increase of the phenomenon with current climate change, systematic studies are lacking in the literature.

This research aims to face the problem from a modelling point of view, with the central objective of deriving an automated physics-based procedure able to simulate correctly, with proper 2D depth-integrated models, the clogging process within large-scale hyper-concentrated and debris flow scenarios. This aim implies an experimental study necessary to characterize the process, individuate the main parameters controlling it and provide data to validate the numerical model. Moreover, since the bed is often non-erodible under the bridges, the study must also evaluate the possible influence of a rigid bed or beds covered by thin layers of sediments on heavy sediment transport.

Beyond the above-mentioned procedure, the expected outcomes of the research are: a collection of field cases and possible relevant back-analyses; some papers in appropriate journals; an operative guideline for applying the procedure and a set of examples for training purposes.

Curriculum B - Mechanics, Materials, Chemistry and Energy

- ***Reference persons:*** **Maria Pantano (UNITN/DICAM), Alvise Bagolini (FBK), Andrea Adami (FBK)**

B1 - scholarship on reserved topics

Funded by: Fondazione Bruno Kessler (FBK) – Department of Civil, Environmental and Mechanical Engineering

Title: Development of ultra-thin films for high-performance miniaturized devices

Low-dimensional materials, such as films with micro/nanometer thickness, can be valuable building blocks of devices and composite structures with novel functions and performances, ranging from extremely miniaturized electronic devices to flexible ones. To exploit the great potential of such materials into high-performance yet reliable and robust devices, a deep understanding of their response to mechanical stimuli is required. However, the unique topology of small-length-scale materials poses many challenges to a deep comprehension of their mechanical properties, requiring the need for high-resolution load and displacement sensors in mechanical tests along with completely new experimental strategies effective for manipulating micro/nanosized components.

During this research project, different activities will be carried out, ranging from the development of plasma enhanced deposition (PECVD) techniques for the deposition of nanoscale films compatible with Micro Electro Mechanical Systems (MEMS) technology, especially based on silicon carbide (SiC), to their characterization and implementation in MEMS-based high-performance devices. Analytical models or numerical analyses using Finite Element Method (FEM) will support the mechanical/electromechanical design of the devices to be developed or of the experimental setups for nanomaterial mechanical characterization. Then, experimental testing of the fabricated materials and devices will be conducted to validate the design.

The results of the research activities will be collected in contributions submitted to international scientific journals and presented at international conferences.

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Collaboration with UniTrento. If UniTrento academic staff contribute to research results obtained through PhD scholarships funded by FBK, the determination of IP shares will be defined through separate written agreements based on each party's contribution. PhD students are required to collaborate with UniTrento in all necessary activities related to the joint management of IP.

- ***Reference person:*** **Vincenzo Trovato (UNITN/DICAM)**

Participant: Ing. Edoardo Macchi (FBK)

B2 - scholarship on reserved topics

Funded by: Fondazione Bruno Kessler (FBK) within the project IPCEI Batterie 2, CUP B62C22000010001 – Department of Civil, Environmental and Mechanical Engineering

Title: *Enabling the energy transition exploiting the battery storage flexibility: a comprehensive system-level and asset-level approach*

Project Description:

Battery Energy Storage System (BESS) are expected to play a key-role in reaching the EU objectives concerning the reduction of carbon emissions. In fact, BESS would contribute to ensure resilient and reliable low-carbon power networks, which will be ever more characterized by intermittent and variable Renewable Energy Sources (RES). Nonetheless, the growing penetration of inverter-connected RES in power systems may potentially affect the grid stability, especially during frequency events caused by a sudden large infeed loss. BESS would alleviate this issue by rapidly varying the power output in response to frequency changes. In addition, BESS can arbitrage with energy market prices, contributing to flatten the energy consumption curve, and thus facilitating the integration of RES. The combination of BESS with other electrochemical

storage system such as supercapacitor into Hybrid Energy Storage System (HESS) can also provide additional flexibility and ultra-fast services.

Recently, Grid Forming (GFM) converters - as interface between the BESS and the main network - gained significant interest over traditional configurations, since they would grant extremely fast response from BESS, which is proportional to the system frequency evolution (i.e. damping response) and its rate of change (i.e. inertial response). The deployment of BESS equipped with GFM converters may positively re-design the pathway towards the implementation of a true low-carbon power network. Nonetheless, at the moment, the research and development and regulatory preparedness in this field is limited. Although asset-level pilot projects are being carried out, the proper assessment of the operation and control of a power system dominated by a BESS with GMF converters remains unclear.

In this context, the fundamental objectives of this Ph.D. project are listed below and included in three major work-packages:

- **WP1: Unlocking BESS flexibility at system-level**: The first objective of this research is to develop a system-level scheduling model which accounts for the BESS' ability to provide inertial and damping response and support system-level frequency response transient dynamics. Moreover, the proposed model shall provide insights on the actual competition between BESS (short-duration and long-duration types, including redox flow batteries) or HESS and other sources of ancillary services (e.g. pumped-hydro storage, synchronous compensators, demand response, conventional units etc.). Hence, the objective is to optimize system-level requirements of services to ensure safe rate of change of frequency, frequency nadirs and quasi-steady state levels, avoiding unnecessary overscheduling of the BESS headroom. Moreover, the model will explicitly consider the effect of the energy recovery after delivering long term services so that its deliverability from storage assets is always guaranteed. The comprehensive model will also inform on the actual system-level economic value for BESS' or HESS' flexibility aiming to define fair prices for actual ancillary services. Eventually, the results of this WP may contribute to the definition of a new and more system-oriented definition of the electricity market design.
- **WP2: Assessment of feasible future scenarios**. The second objective is to develop a flexible simulation platform that effectively replicates the dynamic behavior of actual power networks (e.g. the Italian, the British, the European ones). This platform is needed to study and prove up to which extent the inertial and damping response of BESS with GFM can substitute the rotational inertial and damping response of traditional synchronous generators. In fact, the risk of saturation for BESS with GFM could potentially limit the actual contribution from these assets. In particular, the platform will allow to measure the impact of the spatial distribution of the assets providing ancillary services as well as the impact of current-dependent saturation control schemes of GFMs for BESS. This would provide the Ph.D. project with additional critical knowledge concerning the optimal location of BESS in the system. It will also provide insights on the feasibility and stability of future network topologies. In fact, in future, power networks may envisage large shares of renewable units located off-shore and thus electrically distant from load centers. This is a completely different paradigm compared to traditional networks characterized by a homogeneous distribution of natural inertia provided by synchronous power plants. This model shall eventually inform on the actual system-level needs for capacity and thus shape the size and regulatory framework of the Capacity Markets or other similar examples (e.g. the Italian MACSE).
- **WP3. Evaluation of the main asset-level drivers enabling BESS flexibility.** The validation of the models and results obtained in WP1 and WP2 will rely on detailed laboratory tests to validate the actual capability of several BESS/HESS coupled with grid-following or GFM converters to provide certain fast-responding services. While doing so, different types of BESS (e.g., Li-ion, Na-ion, flow batteries, $NaNiCl_2$) will be characterized and accurate models will be developed. Moreover, in order to test the dynamic support to the frequency transient evolution and the effectiveness of in-house control strategies, the third objective will develop a hardware-in-the-loop setup letting an actual BESS interface itself with a dynamic model of the power system. Moreover, the operational decisions of the BESS will need to account for energy capacity degradation aspects. Thus, the WP3 will also aim to test and develop accurate degradation curves for BESS. These curves will be embedded in dedicated optimization models in the form of constraints and will contribute to the definition of the optimal operation of the asset. Finally, the third WP of this Ph.D. proposal will explore the advantages of operating the BESS in a variety of ancillary services' markets (e.g. intra-day, balancing, MACSE, capacity markets, besides the traditional day-ahead market).

Additional skills:

The ideal Ph.D. candidate should be able to demonstrate knowledge of the Italian and European framework in the context of electricity markets and smart grids. Also, the ideal candidate should have experience with the development and resolution of Mixed-Integer Linear Programming problems in the context of power system scheduling accounting for ancillary services. Finally, the ideal candidate should be able to demonstrate ability in the development of optimization-related software in the Julia-Jump environment. Laboratory experience related to battery system testing and/or electrical measurements is also greatly valued given the nature of the proposed work.

Research Outcomes:

The main tasks facilitating the promotion of the results of the Ph.D. program are:

- The submission of scientific articles to high-impact international peer-reviewed journals. Where possible, the open access publication option will be chosen in order to support the dissemination of the research to the Industry and Institutions.
- Presentation of the results achieved at national and international conferences and to technical exhibitions.
- Organization of dissemination and exploitation events, such as seminars for researchers and workshops for industrial partners or other external relevant stakeholders.

Funding:

This PhD grant is co-funded by FBK through project IPCEI Batterie 2, CUP B62C22000010001.

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Curriculum C - Modelling and Simulation

- *Reference person:* Davide Noè Gorini (UNITN/DICAM)

Participants: CERN (Switzerland)

C1 - scholarship on reserved topics

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering.

Title: Quantum-assisted framework for MEGA-scale seismic evaluation of the CERN's large hadron collider (project: QuMegaCERN)

The successful candidate will contribute to the development of a novel Quantum-based framework for territorial simulations of strategic Infrastructures exposed to natural hazards. The Quantum framework will be deployed for high-fidelity seismic evaluations of CERN underground infrastructures hosting the Large Hadron Collider (LHC), its injectors and experiments.
An advanced Mega-Scale numerical model of the Soil-Infrastructure system will be developed, capturing the multi-physics dynamic interactions between the 50 km-long CERN particle accelerator complex and the surrounding subsoil. Due to the remarkable computational complexity, this challenge will be addressed exploiting Quantum algorithms and Quantum simulators.

The ideal candidate should have a strong background in Computational Mechanics. Knowledge of Finite Element Analysis, Quantum Algorithms and Computing is highly desirable. Experience with tools such as OpenSees, ABAQUS, MATLAB/Simulink or Python is particularly valued. More broadly, candidates with advanced programming skills are encouraged to apply.
This highly multidisciplinary project will greatly benefit from a strong collaboration with the European Organization for Nuclear Research (CERN, Switzerland) and international partners. As such, the PhD program offers the opportunity to spend a research period abroad, during which the selected candidate will work closely with experts in the field.

The main goals of the path are grouped below.

1. Development of a Quantum-HPC integrated workflow for mega-scale engineering applications.

2. Implementation of a mega-scale numerical model of the CERN underground infrastructural system and the surrounding soil for high fidelity seismic simulations.

3. Seismic demands for the CERN strategic underground infrastructures and identification of critical components.

- *Reference person:* Andrea Massa (UNITN/DICAM)

Participants: Giacomo Oliveri (UNITN/DICAM), Paolo Rocca (UNITN/DICAM), Marco Salucci (UNITN/DICAM)

C2 - scholarship on reserved topics

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering.

Title: Environmental Electromagnetics

The transition toward smart and sustainable environments is crucial for addressing global environmental challenges and optimizing the management of the resources. Electromagnetic (EM) technologies offer transformative potential in enabling intelligent sensing, monitoring, and predictive capabilities, facilitating real-time environmental awareness and decision-making. This research project seeks to develop advanced EM methodologies, from radar sensing to inversion and imaging techniques, coupled with artifical intelligence including machine learning and optimization, to create a cooperative, responsive environment that supports sustainability goals and fosters technological innovation. Within this framework, the ELEDIA@UniTN - DICAM research group is carrying out actvities on the development of advanced methodologies for the design, analysis and implementation of innovative electromagnetic technologies.

The objective of the PHD research activity will therefore investigate the development of electromagnetic solutions to support the concept of the smart environment. In addition to EM approaches, the research will also involve multi-physics metamaterial design, with particular emphasis on acoustic metasurfaces and underwater acoustic wave manipulation, aiming to extend the paradigm of smart environments to include novel acoustic sensing and control capabilities, particularly in marine and submerged scenarios.

Accordingly, the attention will be focused on a set of interconnected research areas including the following:

- Radar Sensing Technology for Environmental Monitoring: the research will focus on the design and development of radar-based systems for remote environmental sensing, enabling real-time detection of environmental changes, pollution, and critical events;
- Inversion and Imaging Techniques for Environmental Characterization: the research will focus on the development of novel EM inversion and imaging methodologies aimed to reconstruct environmental parameters, providing detailed insights into subsurface structures, atmospheric conditions, and water quality;
- Machine Learning for Smart Environment Optimization: the reseach will focus on the development of AI-driven models to be integrated with EM data to enhance signal interpretation, predict environmental events, and dynamically adapt sensing strategies, fostering the concept of a responsive smart environment.
- Multi-Physics Metamaterials for Environmental Control: The research will include the design and implementation of innovative metamaterials and metasurfaces, especially for acoustic applications, aiming to manipulate wave propagation in complex environments—such as underwater—thereby enabling enhanced sensing, communication, and environmental interaction capabilities.

To this end, the PHD Student will join a trans-disciplinary team of Researchers and Professors working on a wide variety of domains from EM to civil and environmental engineering. The research activity will be conducted under the supervision of the PI/Advisor and the members of the ELEDIA@UniTN - DICAM of the University of Trento.

The **expected outcomes** of this activity can be listed as follows:

1. Review and analysis of the literature on modern EM methods, technologies, and systems for environmental sensing, imaging, prediction and optimization in the framework of smart and sustainable environment applications;
2. Study and development of: next-generation radar systems for environmental sensing; innovative EM inversion methods for accurate environmental reconstruction and monitoring also including AI-driven strategies to improve the environmental prediction, anomaly detection, and decision-making processes;
3. Conceptualize novel EM- and acoustic-based technologies and solutions for smart environmental applications, including the use of multi-physics metamaterials and acoustic metasurfaces;
4. Validate the proposed EM solutions and methodologies in civil and environmental applications, also considering full-wave simulations and experimental data.

Suggested selected references:

[1] N. Anselmi, G. Oliveri, L. Poli, A. Polo, P. Rocca, M. Salucci, and A. Massa, “Breaking the curse of dimensionality in electromagnetics design through optimization empowered by machine learning,” Advances in

ElectromagneticsEmpowered by Artificial Intelligence and Deep Learning, Wiley-IEEE Press, Hoboken, New Jersey, ch. 3, ISBN 9781119853893, Eds. S. D. Campbell and D. Werner, pp. 83-104, 2023.
[2] Massa and M. Salucci, "On the design of complex EM devices and systems through the system-by-design paradigm - A framework for dealing with thecomputationalcomplexity," *IEEE Transactions on Antennas and Propagation*, vol. 70, no. 2, pp. 1328-1343, February 2022.
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[5] A. Massa, P. Rocca, and G. Oliveri, "Compressive sensing in electromagnetics - A review," *IEEE Antennas and Propagation Magazine*, vol. 57, no. 1, pp. 224-238, February 2015.
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[9] G. Oliveri, F. Zardi, G. Gottardi and A. Massa, "Optically-Transparent EM Skins for Outdoor-to-Indoor mm-Wave Wireless Communications,"IEEE Access, vol. 12, pp. 65178-65191, 2024.
[10] G. Oliveri, F. Zardi, L. Tosi and A. Massa, "On the Use of Specular Reflecting Passive EM Skins in NLOS Wireless Backhauling—Performance and Design Guidelines," IEEE Transactions on Antennas and Propagation, vol. 72, no. 10, pp. 7893-7904, Oct. 2024.

- *Reference person:* Ivan Giongo (UNITN/DICAM)

Participant: Jason Ingham (University of Auckland)

C3 - scholarship on reserved topics

Funded by: University of Trento – Department of Civil, Environmental and Mechanical Engineering

Title: Seismic Vulnerability Reduction of Existing RC Buildings: *Mechanical Stitches* for the strengthening of Beams, Columns, and Joints and their integration with Timber-Based Mitigation Strategies

Reinforced concrete (RC) frame buildings constitute a large part of the building stock of many countries. In recent years, the seismic behavior of these structures has been widely studied. While modern construction codes in seismically active regions include design provisions to ensure an adequate level of seismic safety for new buildings, RC structures, built before the introduction of contemporary seismic design principles, do not necessarily meet these standards. Many older RC structures exhibit inadequate reinforcement detailing, including insufficient transverse reinforcement, poor anchorage, and weak beam-to-column joints. As a result, brittle shear failures and joint degradation are common failure mechanisms under seismic loading, often leading to significant structural damage or collapse.

Conventional strengthening techniques include reinforced concrete jacketing, fiber-reinforced polymer (FRP) wrapping, and steel plates. While effective, these methods often introduce challenges related to difficult application in confined spaces, and irreversible modifications to the structure. More recently, dry strengthening techniques, such as the CAM system, have emerged as promising alternatives, allowing for enhanced performance while maintaining the reversibility of interventions.

This research aims to develop and evaluate a novel strengthening technique based on Mechanical Stitches for RC structural components and joints. The technique focuses on the dry post-installation of mechanical strengthening to complement existing stirrups in beams and columns, preventing shear failure. Additionally, it provides adequate reinforcement to beam-column joints to mitigate or prevent crack formation and the resulting brittle failure of the joint. The feasibility and effectiveness of this method will be investigated through numerical simulation and experimental validation.

Furthermore, the integration of local strengthening techniques, based on mechanical stitches and aimed at improving the performance of individual concrete components, with global timber-based seismic mitigation strategies developed by the supervisors' research team (e.g., Strong-backs, RC-TP technique and Timber Vertical Additions) will be investigated. The combination of these approaches, targeting both the component and system level, is expected to improve the overall seismic response and contribute to a more resilient building stock.

Research Objectives

- To evaluate the seismic vulnerability of common RC frames built from the 1950s onwards, identifying the structural weaknesses specific to the most common configurations.

- To develop a novel strengthening method using dry, reversible fasteners for concrete beams, columns, and beam-to-column joints.

- To assess and optimize the mechanical and seismic performance of the proposed technique through numerical and experimental investigations.

- To develop design guidelines for practical and reliable implementation.

Research Methodology

WP1: **Literature Review and State of the Art**

- Investigation of common RC frame structures and detailing practices from the 1950s onwards.

- Review of existing strengthening methods for beams, columns, and joints, with a focus on dry and reversible solutions.

- Review of testing methods and setups.

WP2: **Numerical Modelling and Preliminary Analysis**

- Development of finite element models (FEM) to simulate the behavior of RC beams, columns, and joints before and after strengthening.

- Parametric studies to identify the most promising strengthening configuration for subsequent experimental validation.

WP3: **Experimental Testing**

- Laboratory testing of full-scale RC beams, columns, and joints strengthened with the proposed technique.

- Consideration of supplementary small-scale tests to refine the strengthening technique before full-scale testing.

WP4: **Model Updating, Optimization, and Design Guidelines**

- Refinement of finite element models based on experimental results.

- Development of practical design guidelines for engineers and practitioners.

WP5: Integration of Mechanical Stitches with Timber-Based Retrofit Strategies for a Holistic Approach to Low-Invasive and Reversible Interventions

- Assessment of the incremental performance improvements resulting from the combination of mechanical stitches with different timber-based retrofit strategies.

- Development of design indications for multi-level strengthening approaches targeting both local and global seismic performance.

Expected Outcomes

- A comprehensive assessment of the seismic vulnerability of existing RC frames with the definition of a quantitative catalog of the most representative structural details of frames built in Italt from the 1950s to the 1980s (based on original drawings and specifications).

- A validated strengthening technique using dry and reversible (post-installed) fasteners, demonstrating improved shear resistance and joint integrity.

- Numerical models and experimental data to support further research and practical applications.

- Design recommendations for engineers, enabling the adoption of this novel strengthening approach in real-world scenarios.

- Integration of local strengthening with global timber-based retrofit strategies.

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- Reference person: Annunziato Siviglia (UNITN/DICAM)

Participant: David F. Vetsch (ETH Zurich)

C4 - scholarship on reserved topics

Funded by: University of Trento – ETH Zurich within the project BASEMENT.

Title: *Integration of physics-based river hydrodynamic and morphodynamic modelling with machine learning*

There is a growing consensus that tackling challenging research questions and diverse engineering problems requires innovative approaches that combine traditional physics-based modelling with advanced machine learning (ML). Physics-based models are widely used in engineering and environmental domains, and their ability to accurately simulate complex phenomena is crucial for promoting long-term environmental sustainability and improving quality of life.

This PhD project focuses on the simulation of hydrodynamic and morphodynamic processes in rivers. These simulations are essential for mitigating flood risks, improving our understanding of river dynamics in a changing climate, and informing water resource management decisions.

BASEMENT is a state-of-the-art physics-based model, based on the solution of the Shallow-Water-Exner equations, that has been developed to address these challenges at reach scale. However, like many physics-based models, it has some well-known limitations. These arise from the need to simplify the representation of complex physical processes and the inherent difficulties in selecting appropriate parameters. In contrast, while state-of-the-art machine learning models can sometimes outperform physics-based models given sufficient training data, they may produce results that lack physical consistency.

The goal of this project is the development of a physics-based model that integrates physics-based methods with ML - leaving the specific ML approach open for exploration - to exploit their complementary strengths. The resulting framework can be applied to a range of problems, such as improving prediction accuracy, enhancing parameterizations for missing physics, enabling reduced-order modeling (including sub-grid processes), and generating data for virtual simulations.

The expected outcomes of this project include the development of a novel physics based model that builds on and extends the simulation capabilities of BASEMENT, specifically targeting to capture nonlinear processes in hydrodynamic and morphodynamic river modelling. Research outcomes will be published in scientific journals in the field of modeling of environmental science.

The successful candidate will have a strong background in hydraulic engineering and morphodynamics, solid programming skills (e.g., C++, FORTRAN, Python, MATLAB), and a keen interest in model development. Proficiency in spoken and written English, along with strong communication skills, is essential.

- Reference person: Diego Misseroni (UNITN/DICAM)

C5 - scholarship on reserved topics

Funded by: Department of Civil, Environmental and Mechanical Engineering within the project UE-HE-SUBBIMATT - CUP E63C24000750006 – G.A. 101129911.

Title: *Origami-Inspired Soft Pneumatic Actuators and Architected Metamaterials*

We are looking for a highly motivated PhD candidate to develop soft pneumatic actuators using inflatable systems made from coated textiles, inspired by origami design and architected metamaterials. The goal is to achieve large, controllable shape changes under high internal pressure, enabling new capabilities in soft robotics and adaptive structures.

A key focus of the project is the design and fabrication of a prototype adaptive building envelope—a lightweight, reconfigurable, and durable system that enhances indoor comfort while passively harvesting energy from solar radiation and wind-induced vibrations.

The research will combine mechanical modeling, numerical simulations, and experimental testing. Special attention will be given to multistability, localized deformation, and self-foldability, using tools such as Floquet-Bloch homogenization and both standard and custom finite element software.

We invite candidates with a background in mechanical, civil, materials or aerospace engineering, or related disciplines. Experience in finite element analysis, computational modeling, and hands-on prototyping is highly desirable.

This is a fully funded position within a dynamic, interdisciplinary research environment, with opportunities for collaboration and international mobility.

Research Supervisors: Under the guidance of Prof. Diego Misseroni, coordinator of the research group (https://misseroni.dicam.unitn.it/), you will have the privilege to collaborate with renowned researchers worldwide, including Prof. Glaucio H. Paulino (Princeton University, USA), Prof. Katia Bertoldi (Harvard University), Prof. Pradeep Pratapa (Madras Institute of Technology, India), Prof. Ke Liu (Peking University,

China), Prof. Hanqing Jiang (Westlake University, China), Prof. Zhuang Zhang (Fudan University, China), Prof Americo Cunha Jr (LNCC and UERJ, Brazil). This global collaboration will empower you to enhance your technical skills, broaden your understanding of materials science, mechanics of materials and structures, and develop critical problem-solving abilities.

Curriculum D - Architecture and Planning, Landscape

- Reference persons: Sara Favargiotti (UNITN/DICAM), Marco Ciolli (UNITN/DICAM)

Participant: Francesco Gasperi (Habitech - Distretto Tecnologico Trentino)

D1 - scholarship on reserved topics

Funded by: University of Trento – Habitech.

Title: Approaches across the building lifecycle to reduce the carbon footprint through architecture

Creating a virtuous cycle of long-term carbon sequestration through sustainable forest management and the built environment that include wood-based construction presents a promising strategy for climate change mitigation. This study explores the integration of production forests and the built environment to establish a continuous carbon storage loop. By fostering and optimizing the use of wood from sustainably managed production forests in building construction and ensuring long-term maintenance, carbon remains locked in durable structures, reducing atmospheric CO_2 levels. Additionally, maintaining and retrofitting wooden buildings extends their lifespan, preserving stored carbon while minimizing the need for energy-intensive materials. To achieve this goal there is the need to delve into the effective lifespan of wood products in buildings as well as in the impact of production and conservation procedures. This also includes a deep understanding of the processes and cycles not only of new buildings but also of refurbishments of old buildings for energy efficiency taking into account existing certifications and novel regulations. In the context of new buildings, the carbon credit assessment must incorporate the irreversible reduction in soil carbon sequestration potential resulting from the conversion of land to build surfaces. This approach fosters a circular carbon economy where forests are systematically replenished, harvested wood is efficiently utilized, and buildings function as long-term carbon sinks. The findings provide insights into optimizing forest-

product cycles, enhancing sustainability in the construction sector and in general transforming the built environment into a net contributor to reach global carbon neutrality goals. Expected results will be the definition of design strategies and approaches across the building lifecycle to reduce the carbon footprint through architecture with the framework of regenerative design.

Specifically expected outcomes of the PhD activity can be listed as follows:

1. literature review on building lifecycle, carbon footprint in architecture and engineering, regenerative design to develop a consistent theoretical framework;
2. collection of national and international innovative design experience and approaches as well as certification and normative;
3. experimental design on a one (or more) pilot cases in Trentino (and abroad);
4. developing strategies and tools that are replicable and scalable;
5. communication and dissemination activities: attending national and international events and meetings and elaboration of reports and scientific publications (research indexed papers, essays, etc.);
6. Analysis and Implementation of Carbon Credits.

“Approaches across the building lifecycle to reduce the carbon footprint through architecture” proposes a PhD activity to train an interdisciplinary figure capable of intercepting the needs of professionals with the proactive thrusts of academic research according to a “Learning by doing” approach.

Reference persons: Sara Favargiotti (UNITN/DICAM), Matteo Anderle (Eurac Research)

Participants: Simone Torresin (UNITN/DICAM), Chiara Paniccia (Eurac Research), Tin Oberman (Eurac Research)

D2 - scholarship on reserved topics

Funded by: Eurac Research within the project SOUNDSCAPES FOR ALL (Grant nr. P-25/03-W – CUP D53C24006270007).

Title: SOUNDSCAPES FOR ALL - An integrated framework for the analysis of acoustic environments for humans and non-human species in mountain environments

The concept of soundscape, first introduced in the late 1960s (Schafer, 1969; Southworth, 1969) has evolved into an interdisciplinary field spanning acoustic ecology, engineering, and environmental psychology, among others. While the ISO 12913-1 standard defines soundscape as the acoustic environment as perceived by individuals in context, alternative use of the term from bioacoustics and ecoacoustics emphasize non-human sound sources, such as biophony and geophony (Pijanowski et al., 2011). These separate tracks tackle the analyses of complex acoustic environments in different ways, missing out on the potential of synergy. Recent studies suggest that bridging these fields could enhance our understanding of soundscapes (Ruiz Arana, 2024), particularly in natural environments, where sound contributes to both human well-being and biodiversity assessments.

Soundscape for All aims to develop an integrated framework combining human-centered soundscape methodologies (Oberman et al., 2025) with bioacoustic and ecoacoustic approaches (Lawrence et al., 2023). The project focuses on the Italian Alps, leveraging ongoing biodiversity monitoring, human soundscape research, and state-of-the-art audiovisual testing facilities at University College London.

Key objectives include assessing how psychoacoustic indices inform biodiversity insights, exploring how bioacoustic measures complement ISO/TS 12913-2 methods in visitor perception studies, and developing a unified framework for characterizing human and non-human soundscapes.

Activities include:

- comprehensive literature review
- field monitoring via soundwalks in biomonitored mountain areas
- data analysis
- immersive listening tests at UCL

- framework development.

The ideal candidate has a background either in (human) soundscape studies or environmental acoustics or bioacoustics.

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Reference persons: Gianluca Maracchini (UNITN/DICAM), Rossano Albatici (UNITN/DICAM)

D3 - scholarship on reserved topics

Funded by: University of Trento – ITEA Spa.

Title: Multi-objective Optimization of Building Stock Retrofit Interventions Integrating Traditional and Nature-based Solutions

This research project aims to develop and apply multi-objective optimization methodologies for the design of building retrofit interventions, to simultaneously minimize environmental impacts, life cycle costs, and thermal discomfort. In addition to traditional solutions—such as external insulation using various materials and replacement of heating/cooling systems—the project will investigate advanced, nature-based strategies (e.g., green roofs and living walls) that can enhance the resilience and adaptability of both individual buildings and the broader urban context in the face of climate change.

The research approach includes:

- **Critical Analysis of Available Technologies.** Comparative study of traditional and green solutions for retrofit interventions, evaluating their performance, feasibility, and effectiveness.
- **Definition of Indicators and Assessment Methods.** Selection of measurable parameters (environmental, economic, thermal comfort, and indoor air quality) and adoption of methodologies such as Life Cycle Assessment (LCA) and Life Cycle Costing (LCC).
- **Development of a Multi-objective Optimization Model.** Formulating algorithms and numerical methods (e.g., genetic algorithms, machine learning) to identify optimal retrofit solutions that balance energy performance, costs, environmental impact, and comfort.
- **Application to Real-world Case Studies.** Validation of the proposed model in buildings of different typologies (residential, commercial, etc.) located in urban areas with varying climatic and socio-economic conditions.
- **Evaluation of Urban-scale Benefits.** Estimation of the impact that large-scale retrofit interventions could have on the urban heat island effect and air quality, as well as stormwater management, considering the potential of nature-based urban systems.

Expected research outcomes:

- **Guidelines for Integrated Interventions.** Development of strategies and decision criteria to combine traditional and nature-based solutions, considering energy performance, environmental sustainability, cost, and indoor comfort.
- **Decision Support Model.** Create a tool or platform to guide professionals and public authorities identify the most effective retrofit strategies that align with technical, economic, and sustainability objectives.

- **Urban Adaptation Scenarios.** Evaluation of the positive effects of the widespread adoption of "green" technologies (green roofs, living façades, etc.), particularly regarding reducing surface temperatures, flood risk, and energy consumption.
- **Contribution to Scientific Literature.** Publication of findings in international journals and conferences, enhancing knowledge in optimization, sustainable building practices, and urban resilience.

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Reference persons: Mario Claudio Dejaco (UNITN/DICAM), Lidia Pinti (UNITN/DICAM)

D4 - scholarship on reserved topics

Funded by: University of Trento – INRES Coop.

Title: Construction use risks - Methods and tools for the evaluation, control and reduction of risk factors during the use of buildings

The significant presence of "aged" buildings in public and private real estate, and the lack of resources, highlights the need to keep the as-is condition of buildings and their components under control, safeguarding their conditions of use.

This topic takes on relevance in the case of real estate assets for office use (both public and private) and commercial use, where the safety of third-party users must be guaranteed.

It must also be considered that the data to be analyzed do not only concern technical aspects, but also have economic, social and environmental implications.

Thise research aims to define investigation procedures that, through the definition and use of appropriate survey and analysis tools, allow to:

- collect legal provisions that define "safety obligations" in relation to different intended uses of buildings and related spaces;
- define, for different intended uses, the conditions/situations that may cause risks for the different users of the spaces
- propose a suitable data collection tool on buildings (digital building booklet) and their components;
- develop procedures for analyzing the risk level of buildings and spaces, based on their as-is condition and intended uses;
- propose digital databases for the collection, organization and extraction of data;
- propose probabilistic procedures to analyze historical data on maintenance and risk events related to the as-is condition of buildings and components;
- develop reports to support the definition of investments to ensure real estate assets safety in use in the short, medium and long term.

The procedures used will concern both the application of expeditous investigation methods of survey and classification/evaluation of the as-is condition of the buildings and their parts, and the systematization of probabilistic

procedures for the analysis and control of historical events that have occurred on buildings and assets of a similar type and intended use.

The aim is to propose control and intervention predictive procedures in order to minimize “accidents”.

In addition to technical analyses, it will be appropriate to introduce simplified procedures for the economic/financial control of investments, considering also the social and environmental contexts, consistent with the current attention of investors and users.

Although focusing on the analysis of existing real estate assets, it is believed that what is proposed could also have design implications, not only for the redevelopment of existing assets but also for new design interventions.

During the research, publications and articles are expected to be written. The outcomes of the research will be the implementation of procedures and methodologies for the investigation and control of the as-is condition of buildings and their components, as well as the development of digital tools to support the operators involved in the safety management and control of an asset.

Private operators will provide real case studies (COOP group, both for offices and mall).

It is also planned to discuss and collaborate with research groups from other universities involved in similar and related fields (Politecnico di Milano, Università di Brescia, Napoli Federico II).

Keywords:

digital building booklet; digital data management; safety of use; risk assessment

Candidate must have:

- skills in digital data management and BIM
- adequate knowledge of Italian building legislation
- proficient/fluent in Italian having to interact with Italian operators in the real estate management field.