Open and Reserved Topic Scholarships – Call 35th cycle

Curriculum A: Civil and Environmental Engineering

Nr. 2 Open UNITN Scholarships on the following themes:

Planning, monitoring and management of civil infrastructures in urban and suburban areas; urban dynamics; efficient use of natural resources; environmental fluid mechanics; mechanics of granular media; river morphodynamics; physical limnology; water temperature dynamics; transport processes in heterogeneous and disordered media; transport processes of nutrients and contaminants along river networks, surficial and subsurficial hydrology; atmospheric processes; impact of climate change on environmental resources; ecohydrology; dynamics of contaminants in the air, soil and water bodies; control systems and protection against extreme natural events; waste water treatment; solid waste treatment.

Nr. 2 Reserved Topic Scholarships:

- **A1** - Hydrothermal processing of sewage sludge: recovery of nutrients (N, P) and energy valorization
- **A2 -** Effects of climate change and human exploitation on groundwater resources in a meso-scale watershed

A1 (UNITN and DICAM scholarship)

Hydrothermal processing of sewage sludge: recovery of nutrients (N, P) and energy valorization
P.I.: Gianni Andreottola (UNITN), Luca Fiori (UNITN)
Waste water treatment plants (WWTPs) produce a substantial amount of sludge which has to be managed and whose disposal is extremely costly (around 100 euro/ton sludge to be disposed of). Hydrothermal processes (HPs) represent technological viable treatments that can be easily integrated in WWTPs in order to decrease the amount of sludge to dispose of and, even better, to recover materials and energy. In this PhD, among HPs, hydrothermal carbonization (HTC) and thermal hydrolysis (TH) will be tested in the frame of WWTPs. Through HTC, the sludge is converted into a solid fraction (referred to as hydrochar) enriched in carbon and P, and a liquid fraction, rich in nitrogen compounds. Both fractions will be valorized: the hydrochar as an adsorbent medium and through further processing to extract P; the liquid fraction as additional biogas source (through anaerobic digestion) and for N recovery. In addition, TH will be tested in order to increase biogas production and decrease digested sludge to be disposed of. Research outcomes are expected to be published in high impact factor journals in the civil engineering (in particular in the WWTPs sector) and chemical engineering areas. The approach of this PhD research will be engineering: science and its actual implementation in real-scale industrial scenarios.

A2 *(MIUR scholarship – Dipartimenti di Eccellenza)*

Effects of climate change and human exploitation on groundwater resources in a meso-scale watershed

P.I.: Bruno Majone (UNITN), Alberto Bellin (UNITN)

Evaluation of climate change impacts on water resources is indisputably a "hot" topic in Hydrological Sciences which is capturing growing attention from scientists, managers and policy makers in addition to the general public. In particular, the effects of future climate and water use scenario, possibly leading to groundwater overexploitation, deserve particular attention due to the important role of groundwater for irrigation, urban consumptions and ecosystem sustainability (e.g. 2000/60/EC and 2007/118/EC). In this contest, reliable projections of long-term evolution of groundwater dynamics are of a paramount importance to settle advanced and sustainable adaptation and mitigation plans considering both climate change and linked human effects.
Groundwater resources are indeed related to climate change through the direct interaction with surface water resources, such as lakes and rivers, and indirectly through the recharge process. Therefore, quantifying the impact of climate change on groundwater resources requires an accurate estimation of the spatio-temporal distribution of groundwater recharge, in addition to a reliable simulation of groundwater flows possibly including the role of heterogeneity in soil hydraulic properties.
This latter aspect deserves particular attention due to the non linear interplay between external forcing and soil and aquifer heterogeneity acting at all scales from local to global. Although aquifer heterogeneity and its effect on flow and transport has been studied in great detail in the last decades in stochastic groundwater hydrology, the implementation of similar techniques to the simulation of the overall watershed hydrologic responses (i.e., joint evaluation of river streamflow and groundwater dynamics) is missing in the hydrological literature, especially at large spatial scales.
Within this framework, distributed hydrological modeling will represent an excellent tool to unveil the complex relationships between climate, human exploitation and groundwater dynamics and to estimate their joint evolution. The analysis will be conducted by means of a suite of hydrological models. In particular we propose to further develop HYPERstreamHS, a distributed model recently developed by the Hydrology group of the University of Trento by including different modules dealing with groundwater storage dynamics: from simple lumped travel time formulations to more sophisticated process-based groundwater models like e.g. Modflow. The various approaches will be then compared to understand to which extent heterogeneity in aquifer hydraulic properties shape both streamflow and groundwater dynamics.
The ideal case study to assess the effects of climate change and human exploitation on groundwater resources is the Northern part of Italy including both the Alpine and Padanian regions, with the latter being a densely populated area including one of the most important aquifers in Italy, i.e., the Po valley aquifer. A preliminary set-up of the modeling framework will be created for the Adige river basin (about 10000 km^2) in order to take advantage from well-instrumented test sites, excellent data availability and established collaborations with regional authorities.

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

1. Improvement of HYPERstreamHS in order to incorporate explicitly groundwater dynamics. Long time series of groundwater levels and streamflows will be used in a multi-objective calibration framework in order to better identify subsurface flows and groundwater recharge.

2. Full coupling of Modflow groundwater model with HYPERstreamHS. In this case particular emphasis will be given to the reproduction of the heterogeneity in the hydraulic properties of the aquifer.
3. Identification and attribution of the main drivers controlling groundwater dynamics in the Adige river basin through trend analysis of available and/or simulated long-term time series of hydrometeorological variables (e.g., precipitation, temperature, snow accumulation, etc.).
4. Implementation of the modeling framework to a meso-scale watershed, i.e. the entire Northern Italy including the Alps and the Po floodplain (about 120.000 km^2). In this case the added value of using both monthly time-lapse gravity field estimates provided by the Gravity Recovery and Climate Experiment (GRACE, http://science.nasa.gov/missions/grace/) and groundwater levels data) will be explored in a multi-objective calibration framework, with the aim to reduce epistemic and model parametric uncertainty.
5. Climate change impact assessment on groundwater resources in the aforementioned meso-scale watershed using an ensemble of meteorological forcing projection scenarios available in the EURO-CORDEX experiment.
6. Evaluation of the combined effects on groundwater resources of concurrent changes in climate and water uses by considering different scenario of groundwater exploitation.

The ideal candidate will have a background in Civil or Environmental Engineering or related fields, ability to develop her/his research activities with high level of autonomy, strong motivation, excellent communication skills (written and oral), and a positive attitude towards integrating this research project within a wider research group. Since foreseen activities include model development, the candidate is required to have computational proficiency (or the will to pursue them) preferably in fortran and python/Matlab. It is intended that the developed tools and/or models are produced as free software.

Suggested references (to be not considered as exhaustive for the topic):

Bellin, A., Majone, B., Cainelli, O., Alberici, D., and Villa, F., 2016. A continuous coupled hydrological and water resources management model. Environmental Modelling and Software, 75, art. no. 3541, pp. 176-192, doi:10.1016/j.envsoft.2015.10.013.

Clark, M. P., Y. Fan, D. M. Lawrence, J. C. Adam, D. Bolster, D. J. Gochis, R. P. Hooper, M. Kumar, L. R. Leung, D. S. Mackay, R. M. Maxwell, C. Shen, S. C. Swenson, and X. Zeng, 2015. Improving the representation of hydrologic processes in Earth System Models, Water Resour. Res., 51, 5929–5956, doi:10.1002/2015WR017096.

I.E.M. de Graaf, L.P.H. van Beek, Y. Wada, M.F.P. Bierkens, 2014. Dynamic attribution of global water demand to surface water and groundwater resources: Effects of abstractions and return flows on river discharges. Advances in Water Resources 64 (2014) 21–33, doi:10.1016/j.advwatres.2013.12.002.

I.E.M. de Graaf, L.P.H. van Beek, T. Gleeson, N. Moosdorf, O. Schmitz, E.H. Sutanudjaja, M.F.P. Bierkens, 2017. A global-scale two-layer transient groundwater model: Development and application to groundwater depletion. Advances in Water Resources 102 (2017) 53–67, doi: 10.1016/j.advwatres.2017.01.01.

Diamantini, E., Lutz, S.R., Mallucci, S., Majone, B., Merz, R., Bellin, A., 2018. Driver detection of water quality trends in three large European river basins. Science of the Total Environment, 612, pp. 49-62, doi: 10.1016/j.scitotenv.2017.08.172.

Diamantini, E., Mallucci, S., Bellin, A. 2019 A parsimonious transport model of emerging contaminants at the river network scale. Hydrol. Earth Syst. Sci., 23(1): 573-593,

doi:10.5194/hess-23-573-2019.

L. Laiti, S. Mallucci, S. Piccolroaz, A. Bellin, D. Zardi, A. Fiori, G. Nikulin and B. Majone, 2018. Testing the hydrological coherence of high-resolution gridded precipitation and temperature datasets. Water Resour. Res., 54, 1999-2016, doi:10.1002/2017WR021633.

Piccolroaz, S., Di Lazzaro, M., Zarlenga, A., Majone, B., Bellin, A., and Fiori, A. 2016. HYPERstream: a multi-scale framework for streamflow routing in large-scale hydrological model. Hydrol. Earth Syst. Sci., 20: 2047–2061, doi:10.5194/hess-20-2047-2016.

Reinecke, R., Foglia, L., Mehl, S., Trautmann, T. Cáceres, D., Döll,P., 2018. Beyond the bucket – Developing a global gradient-based groundwater model (G3M v1.0) for a global hydrological model from scratch, Geosci. Model Dev. Discuss., doi:10.5194/gmd-2018-120.

Curriculum B: Mechanics, Materials, Chemistry and Energy

Nr. 1 Open UNITN Scholarship on the following themes:

Continuum mechanics and thermodynamics in solid and fluid media, as well as in structures, with applications to biomaterials and nanomaterials, micro- and macro-smart structures, geomaterials and multiphase media. Structural control and health monitoring. Structural systems made of different materials, under natural and human exceptional events; risk mitigation and damage reduction; protection of constructed facilities including historic heritage buildings. Residual stresses and surface treatments of mechanical components and devices; engineering materials; innovative materials, with special attention to applications for energy; energy conversion systems and processes, with emphasis on innovation in the use of renewable sources and in the distribution and storage of energy.

Nr. 7 Reserved Topic Scholarships:

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- **B1** - Energy Performance of buildings: Dynamic behavior, performance gap and robustness responding to user behavior
- **B2** - Mechanics of plant roots penetration
- **B3** - Mechanics of legless animal locomotion
- **B4** - Mechanical and strain engineering characterization of 2D nanomaterials
- **B5** - Design and application of MEMS platforms for micromanipulation
- **B6** - Design of high-performance micro-structured materials by using the 3D printing technique
- **B7** - Nanomechanics of wrinkling

B1 ***(UNITN and DICAM scholarship)***

Energy Performance of buildings: Dynamic behavior, performance gap and robustness responding to user behavior
P.I.: Paolo Baggio (UNITN)
Participants: Alessandro Prada (UNITN)
The dynamic behavior of buildings is of fundamental importance in the summer period, but it is also quite significant for the exploitation of the internal heat gains in the winter period, especially when solar gains are high. It is also important to know how a building responds to user behavior (opening of the windows, changing the set-point s, etc.) as

a function of its characteristics (construction methods , thermal capacity of the walls, etc.). Modeling the dynamic behavior usually relies on a deterministic approach (cf. Energy+ and TRNSYS), which does not always allow to describe the effect of user behavior. This also to explain the difference between the expected performances and those actually found. Purpose of the research project is therefore the refinement and verification of the approach to modeling currently used, if necessary developing extensions to the available codes to model the behavior of users as well as the analysis of the possible causes of deviation from the real data. The simulations will also permit the analysis of the thermal comfort conditions within the building as a function of ventilation rates and of thermo-hygrometric parameters and how these conditions can affect the behavior of the users. The expected result will be the evaluation of the "building and HVAC robustness" i.e. the extent to which the overall performance of buildings (both in terms of energy consumption and thermal comfort conditions) may be affected by the behavior of the users for different climatic conditions and characteristics of the building.
The research activity will also include the validation of the models using the data available both on a large scale (for example provincial) and the detailed data directly collected in some buildings.

B2 ***(UNITN and IIT scholarship)***

Mechanics of plant roots penetration

P.I.: Nicola Pugno (UNITN), Barbara Mazzolai (IIT)

Modeling of the penetration of arboreal plant roots in the soil, aimed at the design of bio-inspired robotic systems

The candidate will work on the development models for soil penetration by roots of arboreal plants, aimed at the design of bio-inspired robotic systems able to penetrate the soil to depths of the order of some tens of centimeters. The work will start from the study of the morphometry (dimensions, shape) of roots able to penetrate natural substrates (with particular attention to those of greater impedance), to extract data to set up/calibrate the models and inspire the design of the associated robotic system.

Thus, the study consists of a phase of an in-depth study of the literature in the biological field, in particular regarding the types of roots, the geometry of the root system (diameter, characteristic length of the elongation zone, etc.), also considering the corresponding type of penetrated soil. Based on the data collected and the modeling results, essentially constructed on analytical and/or numerical techniques to be identified during the study itself, the design specifications of the bioinspired robot will be defined. Particular attention will be devoted to the dynamic / adaptive characteristics of the real root, for example through the modulation of the apical diameter to make it functional to penetration / growth.

B3 ***(UNITN and IITscholarship)***

Mechanics of legless animal locomotion

P.I.: Nicola Pugno (UNITN), Barbara Mazzolai (IIT)

We aim at designing new mechanical structures and models for soil exploration inspired by animal organisms that move in soil without legs. The idea focuses on the mechanical study and imitation of locomotion and sensing capabilities of legless organisms, such as

Drosophila larva and fossorial reptiles, with the aim to translate their solutions in soft robots with penetration, navigation and perception abilities. Common features of the environmental conditions that affect the evolving of natural strategies produce convergent adaptive solutions, which can provide exceptional sources of inspiration for artificial artefacts. We will carry out a rigorous mechanical analysis of these different animal solutions in order to extract the strategic benchmarks for developing innovative artificial digging systems, including material mechanical properties, legless locomotion strategies, and sensing abilities (e.g., vibration, gravity, humidity perception). Two main different kinds of soft robots will be studied: a Drosophila larva-like robot and fossorial vertebrate-like robot. The proposed solutions will embody a series of soft and innovative actuators for better adapting the penetration and locomotion in soils of different compactness and type.

The expected scientific breakthroughs concern hierarchical materials endowing multiple properties and functionalities, energy-efficient soft actuation systems, mechanical and kinematics models, and adaptive control.
Scientific and technological impacts are both expected.

B4 *(DICAM and Fondazione Bruno Kessler scholarship)*

Mechanical and strain engineering characterization of 2D nanomaterials

P.I.: Maria F. Pantano (UNITN), Alvise Bagolini (FBK)

Participants: Pierluigi Bellutti (FBK), Nicola Pugno (UNITN)

The advent of low dimensional nanoscale materials, such as nanowires, nanotubes, nanoribbons and more recently two- dimensional (2D) layered nanomaterials has revealed the possibility to fabricate devices and composite structures with novel functions and performances. However, in order to exploit the great potential of nanostructures into high-performance yet reliable devices, we need to know what are the mechanical properties and the main physical phenomena that characterize materials at the micro/nanoscale. For example, in addition to their outstanding strength, 2D nanomaterials are expected to have remarkable strain at break, which provides room for studying how different physical properties vary with mechanical strain (i.e., strain engineering properties).
From a mechanical point of view, a deep comprehension of the properties of nanoscale materials poses many challenges as a direct consequence of their unique topology, which is, in turn, responsible for their unique behavior. High resolution load and displacement sensors are required along with completely new experimental strategies, since the standardized well-assessed methodologies and equipment usually involved at the macroscale are not effective for the manipulation of micro/nanosized components.

During this research project, novel custom-made devices, based on the Micro Electro Mechanical Systems (MEMS) technology, will be developed and applied for the mechanical and strain engineering characterization of 2D nanomaterials.

B5 *(UNITN and Fondazione Bruno Kessler scholarship)*

Design and application of MEMS platforms for micromanipulation

P.I.: Maria F. Pantano (UNITN), Alvise Bagolini (FBK)

Participants: Pierluigi Bellutti (FBK), Nicola Pugno (UNITN)

Mechanical manipulation and characterization of cells and tissues are fundamental

activities in biological and biomedical research. Because of the microscale size and highly fragile nature of the involved materials, conventional cell manipulation and characterization techniques do not provide sufficient accuracy and performances.

In this research project, novel micro electromechanical (MEM) devices based on Silicon-On-Insulator (SOI) wafer micromachining will be developed to manipulate objects in the microscopic scale. The novel micromanipulators will employ thermal and electrostatic actuation and will be designed with dedicated capping parts. Different layouts will be modeled and implemented to evaluate their performance. Sealing techniques will be tested for the device assembly, to enable operation in a liquid environment. Device designs will be compared in terms of both mechanical efficiency and sealing compatibility.
The novel sealed micromanipulators aim at allowing a direct approach to the micromanipulation of cells and tissues.

B6 *(MIUR scholarship – Dipartimenti di Eccellenza)*

Design of high-performance micro-structured materials by using the 3D printing technique

P.I.: Diego Misseroni (UNITN)

Participants: Nicola Pugno (UNITN)

Three-dimensional (3D) printing, originally proposed to fabricate physical prototypes and mock-ups, is attracting more and more interest from the research and application standpoint. Currently additive manufacturing is one of the most promising technique to fabricate advanced materials and microstructures that exhibit properties unattained by homogeneous solids or conventionally manufactured architectures. This project will focus on the use of the 3D printer, bought within the framework of the "Departments of excellence", to design high-performance materials and metamaterials for challenging applications in many engineering and technological fields. Computational methods will be combined with physical models to handle mechanical nonlinearities, to determine constitutive and inertial properties of periodic microstructures, and to design precise and controlled heterogeneous microstructures.

The main goals of the project are listed below:

- design of periodic three-dimensional architected solids at the micro and nanoscale to achieve unique properties, both in statics and dynamics, not attainable by their constituent materials;
- develop of analytical and numerical approaches suitable for modelling the electro-thermo-mechanical behavior of heterogeneous and hierarchical materials, in statics and dynamics;
- use of 3D printing technique together with the time variable (4D printing), to create objects that can be activated in a controlled manner to change shape, configuration or physical properties in response to an external stimulus.

The results of the research will be: (i) published in high impact international journals in the field of mechanics of solids and structures, applied physics, computational mechanics, materials engineering, and additive manufacturing; (ii) presented at national and international conferences.

B7 *(MIUR scholarship – Dipartimenti di Eccellenza)*

Nanomechanics of wrinkling
P.I.: Nicola Pugno (UNITN)
Participants: Massimiliano Fraldi (UNINA), Kostantin Novoselov (NUS)
Wrinkling has recently attracted an increasing interest by suggesting a number of unforeseeable applications in many emerging materials science and engineering fields, in particular with respect to non-planar surfaces patterned at micro- and nano-scales. If guided and somehow designed, wrinkles formation could be for instance used as an alternative 3D printing way for realizing complex surface geometries and thus employed as an innovative bottom-up process in the fabrication of nano- and micro-technological devices. The prediction of wrinkles of films adhering on flat as well as on 3D-shaped compliant substrata is thus a challenging task, the genesis and the development of the phenomenon being not yet completely understood when thin membranes are coupled with soft supports, in cases where the geometry of the surfaces are characterized by complex three-dimensional profiles as well as in man-made films and graphene sheets, for which how underlying micro- or nano-structures influence magnitude, wavelengths and shape of wrinkling is still an open issue. Motivated by the above mentioned applications and by possible uses of wrinkled substrata for analyzing and orienting migration and adhesion of cells, the present project proposal is aimed to ask to the PhD candidate of investigating the experimental formation of new intriguing wrinkled patterns achieved on 3D periodic structures of micro/nano structured films, by adopting both analytical and numerical strategies, by also supporting experimental activities at the laboratory related to the construction and testing of specific prototypes conceived to analyze the effect of the underlying structural geometry on the wrinkling formation. Within the framework of ongoing biomechanical research activities, the candidate will be additionally involved in the study of the functional relationships existing among growing cells adhering and moving on wrinkled surfaces and durotaxis, with the purpose of enhancing the basic understanding of the mechanobiology of living cells and envisaging applications in medicine.

Curriculum C: Modelling and Simulation

Nr. 2 Open UNITN Scholarships on the following themes:

Optimization and application of novel vibration mitigation concepts based on metamaterials. Mathematical and physical modelling and numerical simulation of complex solid and fluid multiscale systems. Bioinspired nanostructures. Atomistic simulation techniques. Computational materials science. Model validation and quantification of uncertainties. Development of numerical algorithms based on finite elements and contour conditions and on meshless Lagrangian methodologies. Finite volume methods for the solution of hyperbolic conservation laws.

Nr. 7 Reserved Topic Scholarships:

- **C1** - Simulation of turbulent transport and exchange processes in the atmospheric boundary layer over mountain regions
- **C2** - Experimental and numerical analysis of steel frames endowed with repairable dissipative seismic components
- **C3** - Global optimization methods to study nanostructured materials

- **C4** - Novel microstructured solids towards the design of ultra-resistant materials under extreme conditions
- **C5** - Novel micro-structured meta-materials with advanced friction properties
- **C6** - Development of novel seismic isolation bearings for structures
- **C7** - Optimization and application of novel protection concepts for pipes: Meta-Pipes

C1 *(UNITN and DICAM scholarship)*

Simulation of turbulent transport and exchange processes in the atmospheric boundary layer over mountain regions
P.I.: Lorenzo Giovannini (UNITN)
The quality of weather forecasts strongly depends on the performance of numerical weather prediction models and areas of complex and mountainous terrain prove to be particularly challenging for numerical models. One of the reasons is that large spatial variations can occur within the atmospheric boundary layer, that is, the lowest layer of the atmosphere. The large heterogeneity of the terrain and differences in vegetation and land use at varying altitudes affect the partitioning of the solar radiation received at the surface and, subsequently, the transport of heat and moisture between the ground and the atmosphere. The transport of heat from the ground is, however, a major driving force for the temperature field within the boundary layer and spatial variations can lead to local wind circulations within mountainous terrain. A correct representation of the exchange of heat, moisture, and also momentum between the land surface and the atmosphere and within the boundary layer is thus crucial for successful model simulations. In numerical models this exchange between the land and the atmosphere and within the atmosphere is handled by the land surface model and the turbulence parameterization, respectively. Potential issues with respect to the performance of these parameterizations in mountainous terrain have been identified. For example, the parameterizations were generally developed based on observations from flat terrain and may thus not be entirely adequate for complex, mountainous terrain. Studies evaluating the performance of the parameterizations in mountainous terrain, however, are scarce. The present research subject aims at evaluating turbulence and land surface parameterizations in mountainous terrain and to identify potential issues with respect to these parameterizations that have a large impact on the model results. Improvements of these specific issues can thus be expected to have a comparatively large positive impact on numerical model simulations and consequently weather forecasts. To evaluate the model performance, model simulations will be performed of individual case studies for different Alpine regions, the Austrian Inn Valley near Innsbruck, the Italian Adige Valley, and the mountain slopes near Bolzano. For these regions, several years of high-quality observational data are available for comparison with the model. The model's sensitivity to changes or potential errors in the turbulence and land surface parameterizations will be evaluated also by means of idealized simulations, that is, certain parameters are modified systematically to quantify their impact on the model results. The candidate will work in the framework of the Euregio project "ASTER – Atmospheric boundary-layer modelling over complex terrain", in strict connection with research groups at the University of Innsbruck and at the Free University of Bolzano. The results of the present project will be presented at international conferences, such as the EGU annual meeting, the International Conference on Alpine Meteorology, the AMS Conference on Mountain Meteorology and the AMS Symposium on Boundary

Layers and Turbulence. Moreover, results are expected to be published in peerreviewed high-ranked international journals.

C2 *(UNITN and DICAM scholarship)*

Experimental and numerical analysis of steel frames endowed with repairable dissipative seismic components

P.I.: Nicola Tondini (UNITN)

Participants: Oreste S. Bursi (UNITN)

Because of their potential for producing high losses and extensive community disruption, earthquakes have been given high priority in efforts to enhance community disaster resilience. Although modern design approaches continue to propose innovative solutions to withstand strong earthquakes, the post-disaster restoration is still too expensive and impactful, both from an economic, social and environmental point of view. Civil structures subjected to strong earthquakes need to dissipate large amounts of energy. This energy dissipation is achieved through development of inelastic deformation in the so-called "dissipative zones" of structural members. This means that conventional systems suffer significant inelastic deformations (costly damages) in main structural elements (steel beams, columns and concrete slabs) and residual storey drifts after a strong seismic event. In this respect, the development and application of easily repairable components are sought to minimize the impact of strong events. Thus, the research will be first focusing on the experimental analysis of steel frames endowed with repairable dissipative devices. The tests will serve to demonstrate the capability of such components to exhibit large inelastic behaviour as well as the ease of replacement. Substructuring techniques will be employed in order to minimize the cost of the test by keeping the outcomes relevant for the whole building. Numerical calibration of the hysteretic behaviour will then be performed to provide design guidelines. Publication of journal papers are expected.

Research projects concerning the research topic

DISSIPABLE - FULLY DISSIPATIVE AND EASILY REPAIRABLE DEVICES FOR RESILIENT BUILDINGS WITH COMPOSITE STEEL-CONCRETE STRUCTURES – Research Fund for Coal and Steel. P.I. Nicola Tondini & CO P.I. Oreste S. Bursi

C3 *(MIUR scholarship – Dipartimenti di Eccellenza)*

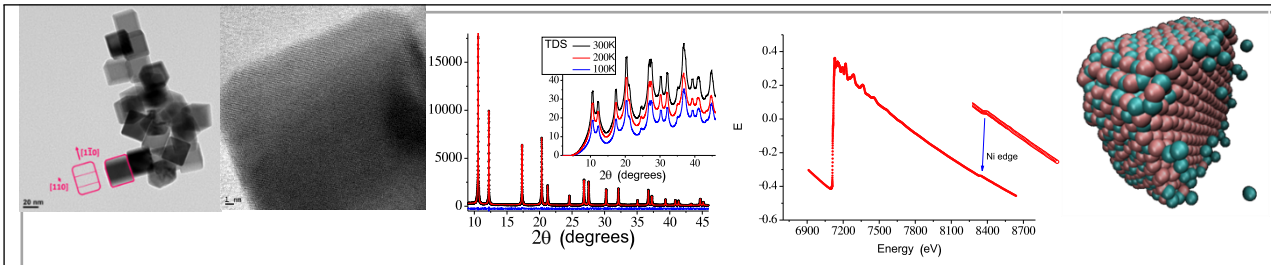
Global optimization methods to study nanostructured materials

P.I.: Paolo Scardi (UNITN)

Participants: Binayak Mukherjee (UNITN PhD student)

Focused on nanocrystalline materials for advanced catalysts, energy harvesting and storage, the project follows the long-standing tradition of our laboratory in X-ray methods, and involves the development of global data optimization algorithms from various X-ray spectroscopy and electron microscopy techniques.

The project mainly involves the development of algorithms, use of advanced software and computer programming to create new global optimization procedures, but also includes involvement in the experimental activity. This especially in synchrotron radiation facilities, for more effective data collection under controlled (in situ, in operando) environmental conditions.



A typical case study, *only one of many*, concerns the kinetic of hydrogen uptake/release in Pd nanocrystals, for storage and catalysis. Here we should blend information from different techniques, such as high-resolution transmission electron microscopy (HR-TEM), X-ray diffraction (XRD) and absorption spectroscopy (XAS) as part of a common global-optimization approach, supported by atomistic models based on Molecular Dynamics (MD) and Density Functional Theory (DFT).

The ideal candidates, in addition to the compulsory Master Degree obtained by 31.10.2019, should have a background in Physics or in Materials Science and Technology, or in Programming/ Information Technology, and a strong will to pursue advanced training and original research, for a career in academic institutions and/or high-tech companies. It is understood that the chosen candidate will be able to take care of the entire project, or focus on some or only one of the planned parts, based on his/her own competences and cultural interests.

C4 *(MIUR scholarship – Dipartimenti di Eccellenza)*

Novel microstructured solids towards the design of ultra-resistant materials under extreme conditions

P.I.: Andrea Piccolroaz (UNITN), Francesco Dal Corso (UNITN)

Architected microstructured materials pave the way for achieving superior mechanical performances under extreme conditions through the optimization of the microstructure properties as geometry, stiffness, and strength. For example, the effective relative stiffness for a solid with a fixed domain can be optimized as a function of the weight by exploiting specific geometry of the lattice composing the material. This opens the way to the engineerization of new topological materials for a variety of exciting applications, ranging from statics (controlled stress design, adaptive mechanical properties, controlled mechanisms, floppy modes) to dynamics (vibration isolation, acoustic waveguiding, elastic wave focusing and superlensing effects) [1,2,3].
Towards the exploitation of mechanical instabilities for reaching improved strength and stiffness and enhanced energy dissipation, lattice structures with soft and/or prestressed links will be considered. Innovative mechanical responses of structures will be first investigated as related to the presence of configurational and movable constraints. The homogenization of such structures will be then pursued via both energetic and dynamical approaches, allowing for first and second-order approximations. This will lead to the identification of Cauchy and higher-order equivalent continua, which will be exploited for the analysis of global instabilities, whereas local instabilities will be analyzed through a Bloch-Floquet technique.
The research activity will be performed through a blend of theoretical, numerical and experimental approaches.

[1] J.-P. Xia, D. Jia, H.-X. Sun, S.-Q. Yuan, Y. Ge, Q.-R. Si, and X.-J. Liu. (2018) Programmable Coding Acoustic Topological Insulator. In: Adv. Mater. 30.46, p. 1805002.

[2] Bordiga, G., Cabras, L., Bigoni, D., Piccolroaz, A. (2019) Free and forcd wave propagation in a Rayleigh-beam grid: Flat bands, Dirac cones, and vibration localization vs isotropization. *International Journal of Solids and Structures*, **161**, 64-81.
[3] Bordiga, G., Cabras, L., Piccolroaz, A., Bigoni, D. (2019) Prestress tuning of negative refraction and wave channeling from flexural sources. *Applied Physics Letters*, **114**, 041901.

C5 *(Marie Sklodowska-Curie ITN INSPIRE – ref. ESR06)*

Novel micro-structured meta-materials with advanced friction properties

P.I.: Davide Bigoni (UNITN), Francesco Dal Corso (UNITN)

Participants: Oreste S. Bursi, M. Gabriella Castellano (FIP), Samuele Infanti (FIP)

The PhD candidate will analyse the possibility of developing dissipators based on assembling structures capable of self-oscillating under a steady input, as in the nonconservative case of follower forces. These structures will exploit dissipation instabilities occurring in frictional devices capable of freely rotating about an axis and thus realizing highly anisotropic friction. The design of these dissipative structures will be pursued to induce non-constant, follower forces from a seismic input. Starting from analyses of discrete models, for which only integration in time is involved, two and three-dimensional dissipative systems will be designed and realized. The research activity will combine dynamic simulations developed within the nonlinear range due to large deflections and/or non-conservativeness of the loading, and experimental demonstrations on small scale prototypes.
Numerical routines will be made available for the analysis of discrete models. Design of frictional/nonlinear dissipators will be pursued. Small-scale prototype of frictional dissipators will be realized.

The candidate will be expected to spend 3 Months at FIP mec srl in Padua (Italy) and 3 Months at JRC –Joint Research Centre – European Commission in Ispra (Italy) as part of secondment contracts.

C6 *(Marie Sklodowska-Curie ITN INSPIRE- ref. ESR08)*

Development of novel seismic isolation bearings for structures

P.I.: Davide Bigoni (UNITN), Samuele Infanti (FIP)

Participants: Oreste S. Bursi (UNITN), Francesco Dal Corso (UNITN), Maria Gabriella Castellano (FIP)

The major objective of the PhD position is the design, and possibly manufacturing and testing, of novel materials (i.e. metamaterials) for vibration control of civil structures and infrastructure.
Specifically, the successful candidate will be expected to develop a comprehensive framework for the optimal design of metamaterials (e.g. topology optimization, sizing optimization) for seismic protection of civil structures and infrastructure, in particular seismic isolation. The key design philosophy is the placement of matter where it serves a specific function in an optimal way while removing matter wherever allowed.
The main research outcome will include the design of the novel materials with unprecedented mechanical properties for seismic isolation. Further development will include the investigation of manufacturing processes, in particular through additive manufacturing, for fabrication of vibration control devices made of the novel class of

materials. Specific testing procedure for the novel materials will be investigated as well. This position will leverage FIP resources in the area of seismic isolation and testing in this field.

The candidate will be hosted by FIP mec srl in Selvazzano Dentro, near Padua (Italy) and will be expected to spend 6 months at University of Trento as well as 3 Months at JRC –Joint Research Centre – European Commission in Ispra (Italy) as part of secondment contracts.

C7 *(Marie Sklodowska-Curie ITN INSPIRE- ref. ESR10)*

Optimization and application of novel protection concepts for pipes: Meta-Pipes

P.I.: Oreste S. Bursi (UNITN), G. Fischbach (IGF)

The ESR will develop and apply structural dynamic-based methodologies for assessing coupled piping-rack systems in typical petrochemical/process plant subjected to NaTech threats. Therefore, he/she will consider coupled piping-rack systems subjected to a systematic list of top events and accident conditions caused by hazards on components leading to a loss of containment or physical damage owing to natural/man-made hazards including explosion/fire. Thus, performance levels and critical scenarios will be examined.

The novel concept of periodic metamaterials or metastructures will be applied to the optimal vibration mitigation of piping systems subjected to both bending or axial waves. In greater detail and with regard to vibrations due to natural/man-made hazards, new pipe layouts will be conceived with novel periodic resonators. Moreover, small pipes can also be treated as resonating systems by themselves and nonlinear mechanism for vibration reductions will be accounted for. Consideration of additional meta-material approaches e.g. "thermal-metamaterials" for the protection from related hazards, e.g. fires, temperature, will be taken into account. These novel design concepts will also be explored for other examples of important symmetric structures, like pipes used in regasification stations or the reactors of nuclear power plants.

The candidate will be hosted by IGF in Erftstadt (Germany) and is expected to spend 6 months at University of Trento as well as 3 Months at JRC –Joint Research Centre – European Commission in Ispra (Italy) as part of secondment contracts.

Curriculum D: Architecture and Planning, Landscape

Nr. 2 Reserved Topic Scholarships:

- **D1** - Adaptation strategies for climate-resilient, energy-efficient and RES-based urban eco-systems
- **D2** - BRANDING 4 RESILIENCE. Tourist infrastructure as a tool to enhance small villages by drawing resilient communities and new open habitats

D1 *(UNITN and DICAM scholarship)*

Adaptation strategies for climate-resilient, energy-efficient and RES-based urban eco-systems

P.I.: Rossano Albatici (UNITN), Sara Favargiotti (UNITN)

The research project concerns the development of a novel urban and building design approach, based on both passive and active constructive-technological systems, as well as in the use of Renewable Energy production Technologies - RETs - to be considered in urban planning and in new buildings as well as in the restoration process, in order to face the challenges linked to climate change effects. Climate mitigation and adaptive solutions will be considered and experimented, capable to evolve towards a multi-functional and interactive system, and to respond to multiple inputs for different degrees of adaptability and resilience.

The research will be developed on real case studies, where the urban dimension will be considered as well, in order to build innovative urban adaptation platforms with the support of shared community services, regenerative refurbishment and sustainable renewable energy exploitation, also improving the local economy.

In this context, the aspects concerned with a better understanding of the legal framework and the daily practice in urban landscapes characterized by the presence of RETs will be stressed, considering that the individual and the social dimensions have a great influence on overcoming the existing barriers refraining change in energy production and consumption.

The main issues to be faced are:

1. to develop a design approach for a new generation of adaptive, intelligent, behaviour-driven and climate resilient envelopes/buildings integrated in urban eco-systems;
2. to define new possibilities for the exploitation of innovative/smart technologies with the integration of IoT (Internet of Things) for buildings that will have important consequences on living and occupying indoor and outdoor spaces;
3. to deepen in the behaviours of the population as concerns energy challenges, investigating people's perceptions of new "energy landscapes" as well as the behaviours of the energy consumers in the everyday life together with consumer engagement and social innovation on renewable energy;
4. to define methods to integrate nature-based and technology-based mitigation and adaptation solutions at the urban and at the building scales which can be socially accepted, also considering existing legal frameworks.

Expected research outcomes:

1. definition and analysis of the most important features and parameters connected to the adaptive envelope, climate-resilient and energy-efficient concepts;
2. proposal of a design strategy/approach to consider environmental issues and indoor comfort conditions, also with the use of innovative/smart technologies and with the integration of IoT;
3. design guidelines for a new generation of urban spaces where buildings, open/common spaces and people/users are connected in a climate-resilient, energy-efficient and RES-based urban eco-system;
4. definition and analysis of methods and indicators to establish the level of engagement of the population to remove the existing barriers to renewable energies and energy efficiency
5. Papers on international journal and participation to conferences.

D2 *(UNITN scholarship)*

BRANDING 4 RESILIENCE. Tourist infrastructure as a tool to enhance small villages by drawing resilient communities and new open habitats
P.I.: Sara Favargiotti (DICAM/UNITN)
Participants: Alberto Nucciarelli (DEM-UNITN)

The doctoral candidate will be involved in the research project of BRANDING4RESILIENCE (B4R). The research project will investigate the potential of branding in defining drawing resilient communities to enhance small villages characterized by minimal tourist infrastructures. He/She will analyze selected territories and give inputs for co-designing actions and co-visioning scenarios. He/She will contribute to develop a new understanding and use of cultural heritage and local resources targeted at transforming spaces through minimal design interventions and opening business development opportunities at different scales and with different time perspectives.

Research focuses

In accordance to B4R topics, the doctoral candidate will focus on the definition of a territorial brand for specific thermal areas to conceptualize the environmental sustainable with ready-to-use actions. Overall goal is to create healthier and greener living habitat through the widest possible participation of civil society, implementing nature-based solutions focused on the quality of life improvement. The research will specifically addressed the topic on the Trentino region compared and confronted with national and international case studies.

Expected research outcomes

The doctoral candidate will address the following research topics: a) valorization of the resources of landscaping cultural, architectural, environmental, and urban heritage; b) definition of actions and interventions of urban, landscape, architectural and strategic importance for the economic and social development of the urban agglomerates; c) comparative assessment of future scenarios; d) cost-benefit analysis of cultural, architectural and environmental policies; e) definition of a new strategic vision for local stakeholders within the tourism industry.

An exploration and critical analysis of thermal landscape in small villages (inner areas) at national, international context should also be addressed. A map of the blueprint of thermal landscape in Trentino, should be developed by including qualitative systems (nature, culture, heritage) and quantitative dimensions (social, economical, ecological and cultural benefits). At the end of the project, a set of tools of blue and green infrastructures will presented to drive B4R strategy in small villages. These results should produce a "B4R ROADMAP": a process-oriented tool collecting research outcomes and guidelines for knowledge transfer. The roadmap will highlight short and long-term operations, as well as SMLXL scales of interventions, addressing the necessary steps towards more resilient communities and open habitats.

The doctoral candidate will addressed the landscape architecture (ICAR/15) discipline with an emphasis on business models and strategic management (SESC-P/08).